CR-134044

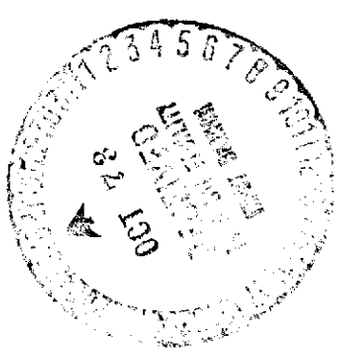
NASA-CR-134044) AN EVALUATION OF THE EFFECTS OF BED REST, SLEEP DEPRIVATION AND DISCONTINUANCE OF TRAINING ON THE PHYSICAL FITNESS OF HIGHLY TRAINED YOUNG (Harding Coll.) 546 p HC $4.50 CSCL 06S
N73-32008
Unclas
G3/04 18708

PROGRESS REPORT FOR NAS-9-9433

An Evaluation of the Effects of Bed Rest, Sleep Deprivation and Discontinuance of Training on the Physical Fitness of Highly Trained Young Men

Harding College, Searcy, Arkansas

September 1, 1972-August 31, 1973



PROGRESS REPORT

Grant Number: NAS-9-9433 "An Evaluation of the Exer-Genie Exerciser and the Collins Pedal Mode Ergometer for Developing Physical Fitness."

Principal Investigator: Harry D. Olree, Ed.D.

Sponsoring Institution: Harding College, Searcy, Arkansas

Period Covered by the Report: September 1, 1972 - August 31, 1973

This report covers Experiment VII of seven experiments to be conducted over a 52-month period beginning May 1, 1969. Experiment I showed that isometric and isotonic training on the Exer-Genie gave negligible increases in cardiorespiratory fitness whereas training on the ergometer at a programmed pulse rate increased fitness moderately. In Experiment II it was found that either (a) exercising on the Collins Pedal Mode Ergometer at 160 pulse rate, ten minutes a day, five days a week, or (b) exercising on the ergometer at 85% maximum pulse rate, ten minutes a day, five days a week would promote moderate increases in fitness. Training in a supine position on the Exer-Genie at 160 pulse rate, twenty minutes a day, five days a week, showed no significant change in fitness. In Experiment III, men 30-45 years old made moderate gains in fitness by exercising three or five days a week for ten minutes a day on a bicycle ergometer at a pulse rate of 85% maximum. A group which worked at this level on the ergometer for three days a week and two days a week on an Exer-Genie circuit made similar gains. In Experiment IV three exercise groups worked on a foot-mode ergometer for twenty minutes a day, three days a week, at 85% maximum pulse rate. On the alternate days one group worked on a hand-mode ergometer for twenty minutes a day at 70% maximum pulse rate, a second group had the same schedule on a hand-mode ergometer at 85% maximum pulse rate, and a third group worked for twenty minutes a day on an Exer-Genie circuit. These groups made slight gains in strength and moderate gains in cardiopulmonary fitness. All the exercise groups in Experiment V made moderate gains in cardiopulmonary fitness. One group worked thirty minutes a day, three days a week, on a hand-mode ergometer at 85% maximum pulse rate. A second group worked thirty minutes a day, three days a week, on a foot-mode ergometer at 85% maximum pulse rate. A third group worked thirty minutes a day, three days a week, on a Universal Gym. The subjects exercising on the Universal Gym gained in arm and shoulder girdle strength and the subjects exercising on the foot-mode ergometer gained in leg strength. A training program to increase both strength and cardiopulmonary fitness was the design of Experiment VI. The three exercise groups worked fifteen minutes a day, three days a week on a foot-mode ergometer at 85% of their maximum heart rate. Each group immediately followed this with an additional fifteen minutes of exercise: one group on a hand-mode ergometer, a second group on an Exer-Genie circuit, and the third on a Super Mini-Gym circuit. All groups made moderate cardiopulmonary gains but only the Exer-Genie and Mini-Gym effectively increased strength.

The authors express appreciation to Dr. Jim Meade, Dr. Robert Walls, Carolyn Thompson, and Mr. Chris Hunter of the Biometry Division, University of Arkansas Medical School, for their assistance in the analysis of the data.

Experiment VII: An Evaluation of the Effects of Bed Rest, Sleep Deprivation and Discontinuance of Training on the Physical Fitness of Highly Trained Young Men

Harry Olree, Bob Corbin, Gene Dugger, Carroll Smith
Harding College
Searcy, Arkansas

I. Introduction

A number of physiological changes, which are in general referred to as deconditioning, result from living in the environment of space. Two possible ways to minimize the effects of deconditioning in space are to achieve a very high level of conditioning immediately prior to flight and provide a regimen in the capsule which will conserve pre-flight physical fitness and maintain a moderate degree of fitness. This laboratory has been investigating methods and equipment to determine how these two goals might be efficiently attained.

It was determined in this laboratory that running and riding a bicycle ergometer at comparable heart rates produced similar gains in physical fitness variables. It was found that subjects who exercised at a 180 heart rate made greater gains in physical fitness than did those exercising at a 140 or 160 heart rate. When the length of the workout was varied, subjects exercising sixty minutes per day made greater gains than those exercising twenty or forty minutes per day. Greater gains on specified components of physical fitness also resulted in subjects who exercised twelve times per week when compared to those who exercised three or six times a week. Subjects who discontinued training slowly deconditioned, but a moderate level of fitness could be maintained by exercising at a pulse rate of 160 beats per minute for twenty-minute periods three times a week. Subjects who "overtrained" twice daily to near exhaustion increased in fitness.

Exercise programs involving two pieces of equipment, the Exer-Genie Exerciser and the Collins Pedal Mode Ergometer, have been investigated. It was found that neither six- nor twelve-minute training periods each day involving isometric and isotonic exercises with an Exer-Genie resulted in significant increases in selected physical fitness variables. Training in a supine position on the Exer-Genie at a 160 pulse rate for twenty minutes per day showed no significant change in fitness. Three training programs involving the Collins Ergometer have been examined. One group of subjects exercised for twelve minutes per day with the heart rate programmed to increase during the training period. Another group exercised for ten minutes a day at 85% of their maximum heart rate while a third group exercised at a 160 heart rate for ten minutes a day. Each of these groups showed moderate increases in fitness.

Moderate gains in physical fitness were produced in three exercise groups of men 30-45 years old who were initially in poor to fair condition. One group exercised for ten minutes a day, three times a week on a bicycle ergometer at 85% maximum pulse rate. Another group exercised for ten minutes a day, five times a week on a bicycle ergometer at 85% maximum pulse rate. The third group exercised for ten minutes a day, three times a week on the bicycle ergometer at 85% maximum pulse rate and two times a week on an Exer-Genie circuit. These three exercise groups made comparable gains in fitness.

A combination of exercises has been investigated. One group of subjects exercised for twenty minutes a day, three days a week, on a foot-mode ergometer at 85% maximum pulse rate and twenty minutes a day, two days a week, on a hand-mode ergometer at 70% maximum pulse rate. A second group had the same schedule but worked on the hand-mode ergometer at 85% maximum pulse rate. The third group exercised for twenty minutes a day, three days a week, on a foot-mode ergometer at 85% maximum pulse rate and two days a week on a seven-station Exer-Genie

circuit. These groups made moderate gains in strength and cardiopulmonary fitness.

Another combination included endurance and strength training in the same workout. The three exercise groups worked fifteen minutes a day, three days a week on a foot-mode ergometer at 85% of their maximum heart rate. Each group immediately followed this with an additional fifteen minutes of exercise. One group completed two circuits on a seven-station Exer-Genie circuit at each exercise session. One group exercised on a hand-mode ergometer. The third group completed two circuits on a seven-station Super Mini-Gym circuit during each exercise session. All groups made moderate cardiopulmonary gains but only the Exer-Genie and the Mini-Gym were effective in increasing strength.

An experiment was performed to compare exercise on equipment designed solely to produce strength, exercise of the lower torso only to produce cardiopulmonary fitness and exercise of the upper torso only so as to produce cardiopulmonary fitness. One group worked thirty minutes a day, three days a week, on a Universal Gym. Another group worked thirty minutes a day, three days a week, on a foot-mode ergometer at 85% of their maximum pulse rate. A third group worked thirty minutes a day, three days a week, on a hand-mode ergometer at 85% of their maximum pulse rate. The group exercising on the Universal Gym gained in arm and shoulder girdle strength. The subjects exercising on the foot-mode ergometer gained in leg strength and all groups made moderate gains in cardiorespiratory fitness.

II. Purpose

The purpose of this experiment was to determine what physiological effects result when highly trained subjects are confined to bed, deprived of sleep or allowed to discontinue training.

III. Methods

The subjects in this experiment were twenty college-age male volunteers whose physical work capacity was above average. Base lines were determined on specified variables by administering the following: (a) a medical examination, (b) anthropometric measurements, (c) the Physical Fitness Index Test, (d) three selected strength measurements, (e) a bicycle test, and (f) biochemical analyses of the blood serum.

The medical examination included a six-lead EKG, a vital capacity test (1), and serum and urine analysis. The following anthropometric measurements were taken: neck, chest, bicep, forearm, waist, thigh, and calf. A Physical Fitness Index (PFI) (2) was obtained for each subject based on his: age, height, weight, vital capacity, grip strength, back strength, leg strength and arm strength. In addition to the PFI, a Strength Quotient was determined by the procedure of Clarke (3). The Strength Quotient is derived from cable-tension tests of shoulder extension, knee extension and ankle plantar flexion.

Blood samples were obtained by venipuncture with the subjects in a resting, fasting state. The following serum determinations were made: glucose by the o-toluidine method (Woods Scientific Company), total protein by a refractometric method supplied by American Optical Company, total lipids by the Dade Company method, phospholipids by the method of Sunderman (4), cholesterol and triglycerides by methods supplied by Oxford Laboratories, and sodium, potassium and calcium on a Coleman flame photometer.

Each subject was given a bicycle test consisting of a five-minute rest period followed by five minutes of work at each of three work levels, 25, 50 and 75% of maximal load. The work load was then increased by 75 kpm per minute until the pulse rate reached 180 beats per minute. Pulse rate and blood pressure, diastolic and systolic, were taken manually each minute during the resting,

recovery, and working phases. Pulmonary ventilation was measured and expired gas samples were collected during the fourth and fifth minutes of the resting, recovery, and exercise phases of the test. Using a single-breath procedure developed by Kim, et al. (5) and modified by Buderer, et al. (6) at the Johnson Spacecraft Center Environmental Physiology Laboratory, measurements were made during the fourth minute of the rest, recovery, and the first three exercise phases, with a Medspect Medical Mass Spectrometer and an X-Y plotter, from which cardiac output was estimated.

By using a table of random numbers the twenty subjects were divided into four groups of five each. Three groups were trained and the fourth served as a control, engaging in their normal daily activities without any specified training program. The training program consisted of running approximately three miles per day, three days a week and working on a Universal Gym for thirty minutes a day, twice a week. The subjects were encouraged to exercise more than the above and many did. The training phase lasted approximately twelve weeks and an intermediate bicycle test was administered to assess physical work capacity. At the end of the training period all subjects were evaluated by administering (a) anthropometric measurements, (b) the Physical Fitness Test, (c) three selected strength measurements, (d) a bicycle test, and (e) biochemical analyses of the blood serum to determine the effect of the training program and to establish new base lines for comparing post-stress measurements.

At this time the trained subjects were stressed. The five subjects in Group A were confined to a horizontal position in bed for five days. They were allowed to get out of bed for bowel movements only. The bathroom was within ten feet of the beds. The subjects in Group B reverted to a normal daily schedule without participating in a training program. The subjects in Group C were kept awake and moving for fifty hours. Group D was the control group.

All subjects were evaluated immediately post-stress by administering (a) a bicycle test, (b) three selected strength measurements, and (c) biochemical analyses of the blood serum. Post-stress, all subjects were required to revert to a normal daily schedule without participation in a training program. Bicycle tests were given every two weeks for six weeks following stress.

The data were analyzed by analysis of variance and Duncan's Multiple Range tests on selected contrasts where indicated. The following model was used for the analysis of variance: $Y_{ijkl} = U + A_i + B_{j(i)} + C_k + E_{l(ijk)}$, where A represents the groups and is considered fixed, B represents the subjects and is considered random, and C represents the tests and is considered fixed. Although there were seven test periods, the data were analyzed two periods at a time.

TABLE I

ANOVA TABLE

Source	Df	E(ms)	F
Total	N-1		
(A) Groups	n-1	(1) $\sigma_E^2 + q\ \sigma_{B(A)}^2 + pq\ \sigma_A^2$	1/2
B(A) Subjects in Groups	n(p-1)	(2) $\sigma_E^2 + q\ \sigma_{B(A)}^2$	
C Tests	(q-1)	(3) $\sigma_E^2 + \sigma_{[B(A)C]}^2 + np\ \sigma_C^2$	3/5
AC Groups, Tests Interaction	(n-1)(q-1)	(4) $\sigma_E^2 + \sigma_{[B(A)]C}^2 + P\ \sigma_{AC}^2$	4/5
[B(A)] C Subjects in Groups, Tests Interaction	n(p-1)(q-1)	(5) $\sigma_E^2 + \sigma_{[B(A)]C}^2$	

In the Anova Table the number of observations (N) is forty for all variables. The number of groups (n) is four, the number of subjects per group (p) is five and the number of tests (q) is two for all variables.

IV. Results

The average age, height, and weight for each group prior to the beginning of the training are given in Table II.

TABLE II

MEAN AGE, HEIGHT, AND WEIGHT OF SUBJECTS

GROUP	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)
A - Bed Rest	18.6	175.2	70.6
B - Quit Training	21.0	175.0	71.6
C - Sleep Deprivation	19.6	170.8	64.8
D - Control	19.6	177.2	66.2
ALL	19.7	174.5	68.3

The significant changes that were found for all variables that were measured pre- and post-training and pre- and post-stress are listed in Tables III and IV, respectively. The significance level is indicated ($p = 0.1$, 0.05, 0.01 or 0.001). A significant decrease is indicated by a minus sign in front of the significance level and a significant increase is indicated by the lack of a sign.

TABLE III

SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES
MEASURED PRE- AND POST-TRAINING

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
ANTHROPOMETRIC MEASUREMENTS				
Neck				
Chest	0.01			0.1
Left Bicep	0.05	0.1		
Right Bicep	0.01	0.1		0.01
Left Forearm	0.1		0.05	
Right Forearm	0.1			
Waist	0.1			
Left Thigh	0.1			
Right Thigh	0.05			
Left Calf	0.1			
Right Calf	0.05			
STRENGTH MEASUREMENTS				
Pullups	0.05	0.01	0.05	0.05
Dips		0.1	0.01	
Arm Strength	0.001	0.001	0.001	
Left Hand Grip				
Right Hand Grip				0.1
Leg Strength			0.05	-0.1
Back Strength				
Strength Index	0.05	0.05	0.001	
Physical Fitness Index		0.1	0.001	

TABLE III...SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-TRAINING....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Shoulder Extension	0.05			-0.05
Knee Extension				
Ankle Plantar Flexion	0.01		0.05	
Strength Quotient		0.1	0.05	
BLOOD ANALYSES				
Protein	-0.1			
Glucose		-0.1		
Total Lipids	-0.01			
Cholesterol	-0.1			
Triglycerides			-0.001	-0.1
Phospholipids			0.01	-0.05
Na^{+}		0.01		
K^{+}	0.001	0.01	0.001	0.01
Ca^{++}			-0.01	-0.001
BICYCLE TEST VARIABLES				
Time on Bike	0.001	0.001	0.001	0.05
Systolic Blood Pressure at Rest				-0.05
Systolic Blood Pressure at 25% Load			-0.01	
Systolic Blood Pressure at 50% Load		0.05		
Systolic Blood Pressure at 75% Load				
Systolic Blood Pressure at 180 p.R.	0.001	0.05	0.05	0.1
Systolic Blood Pressure at Recovery				
Diastolic Blood Pressure at Rest				
Diastolic Blood Pressure at 25% Load	-0.05		-0.05	

TABLE III... SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-TRAINING....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Diastolic Blood Pressure at 50% Load	-0.05		-0.1	
Diastolic Blood Pressure at 75% Load				
Diastolic Blood Pressure at 180 P.R.			-0.1	-0.05
Diastolic Blood Pressure at Recovery	-0.05			-0.1
Pulse Rate at Rest				
Pulse Rate at 25% Load			-0.05	-0.05
Pulse Rate at 50% Load	-0.05	-0.05	-0.01	-0.1
Pulse Rate at 75% Load	-0.001	-0.01	-0.001	
Pulse Rate at 180				
Pulse Rate at Recovery				-0.1
$\dot{V}_E$ BTPS at Rest				
$\dot{V}_E$ BTPS at 25% Load			0.05	
$\dot{V}_E$ BTPS at 50% Load				
$\dot{V}_E$ BTPS at 75% Load				
$\dot{V}_E$ BTPS at 180 P.R.	0.001	0.001	0.001	
$\dot{V}_E$ BTPS at Recovery			0.1	
$\dot{V}_E$ STPD at Rest				
$\dot{V}_E$ STPD at 25% Load			0.05	
$\dot{V}_E$ STPD at 50% Load				
$\dot{V}_E$ STPD at 75% Load				
$\dot{V}_E$ STPD at 180 P.R.	0.001	0.001	0.001	
$\dot{V}_E$ STPD at Recovery			0.1	
Respiratory Rate at Rest				
Respiratory Rate at 25% Load				

TABLE III...SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-TRAINING....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Respiratory Rate at 50% Load	-0.1			
Respiratory Rate at 75% Load		-0.1		
Respiratory Rate at 180 P.R.			0.05	
Respiratory Rate at Recovery		0.05		
Tidal Volume at Rest				0.05
Tidal Volume at 25% Load	0.1			
Tidal Volume at 50% Load				
Tidal Volume at 75% Load				.05
Tidal Volume at 180 P.R.	0.05			
Tidal Volume at Recovery				-0.1
$\dot{V}_{CO_2}$ at Rest				
$\dot{V}_{CO_2}$ at 25% Load			0.1	
$\dot{V}_{CO_2}$ at 50% Load		-0.05	-0.1	
$\dot{V}_{CO_2}$ at 75% Load				
$\dot{V}_{CO_2}$ at 180 P.R.	0.001	0.001	0.001	0.05
$\dot{V}_{CO_2}$ at Recovery				
$\dot{V}_{O_2}$ at Rest				
$\dot{V}_{O_2}$ at 25% Load			0.1	
$\dot{V}_{O_2}$ at 50% Load		-0.05		
$\dot{V}_{O_2}$ at 75% Load				
$\dot{V}_{O_2}$ at 180 P.R.	0.001	0.001	0.001	0.05
$\dot{V}_{O_2}$ at Recovery				
$\dot{V}_{O_2}$/pulse at Rest				
$\dot{V}_{O_2}$/pulse at 25% Load			0.001	0.05

TABLE III...SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-TRAINING....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
$\dot{V}_{O_2}$/pulse at 50% Load	0.1		0.05	0.05
$\dot{V}_{O_2}$/pulse at 75% Load	0.05		0.01 .	
$\dot{V}_{O_2}$/pulse at 180 P.R.	0.001	0.001	0.001	0.01
$\dot{V}_{O_2}$/pulse at Recovery			0.05	
$\dot{V}_{O_2}$/kgbw·min at Rest				
$\dot{V}_{O_2}$/kgbw·min at 25% Load			0.1	
$\dot{V}_{O_2}$/kgbw·min at 50% Load		-0.05		
$\dot{V}_{O_2}$/kgbw·min at 75% Load				
$\dot{V}_{O_2}$/kgbw·min at 180 P.R.	0.001	0.001	0.001	0.001
$\dot{V}_{O_2}$/kgbw·min at Recovery			0.1	
$\dot{V}_E/\dot{V}_{O_2}$ at Rest			0.05	
$\dot{V}_E/\dot{V}_{O_2}$ at 25% Load			0.1	
$\dot{V}_E/\dot{V}_{O_2}$ at 50% Load				
$\dot{V}_E/\dot{V}_{O_2}$ at 75% Load				
$\dot{V}_E/\dot{V}_{O_2}$ at 180 P.R.			0.1	
$\dot{V}_E/\dot{V}_{O_2}$ at Recovery				
Cardiac Output at Rest				
Cardiac Output at 25% Load				
Cardiac Output at 50% Load				
Cardiac Output at 75% Load				
Cardiac Output at Recovery				
Respiratory Exchange Ratio at Rest				
Respiratory Exchange Ratio at 25% Load				
Respiratory Exchange Ratio at 50% Load				

TABLE III...SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-TRAINING....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Respiratory Exchange Ratio at 75% Load		0.1	-0.1	
Respiratory Exchange Ratio at 180 P.R.				
Respiratory Exchange Ratio at Recovery				

TABLE IV

SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES
MEASURED PRE- AND POST-STRESS

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
STRENGTH MEASUREMENTS				
Shoulder Extension	-0.1	-0.1		
Knee Extension				-0.05
Ankle Plantar Flexion				
Strength Quotient			-0.1	
BLOOD ANALYSIS				
Protein	-0.01		0.05	
Glucose			0.1	
Total Lipids	0.1	0.01		
Cholesterol				
Triglycerides	0.05	0.05	-0.1	
Phospholipids			-0.05	
Na^{+}	0.05			
K^{+}				
Ca^{++}				0.05
BICYCLE TEST VARIABLES				
Time on Bike	-0.001		-0.01	
Systolic Blood Pressure at Rest			0.05	
Systolic Blood Pressure at 25% Load			0.05	-0.05
Systolic Blood Pressure at 50% Load				-0.1
Systolic Blood Pressure at 75% Load				
Systolic Blood Pressure at 180 P.R.	-0.01			

TABLE IV.. SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-STRESS....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Systolic Blood Pressure at Recovery				
Diastolic Blood Pressure at Rest	-0.1	0.1		
Diastolic Blood Pressure at 25% Load		0.1	0.01	
Diastolic Blood Pressure at 50% Load			0 .1	
Diastolic Blood Pressure at 75% Load				-0.05
Diastolic Blood Pressure at 180 P.R.				0.05
Diastolic Blood Pressure at Recovery	0.1			
Pulse Rate at Rest	0.05		0.1	
Pulse Rate at 25% Load	0.1		0.1	
Pulse Rate at 50% Load	0.01		0.05	
Pulse Rate at 75% Load	0.001	0.05	0.01	
Pulse Rate at 180				
Pulse Rate at Recovery				
$\dot{V}_E$ BTPS at Rest				
$\dot{V}_E$ BTPS at 25% Load				
$\dot{V}_E$ BTPS at 50% Load				
$\dot{V}_E$ BTPS at 75% Load		0.1		
$\dot{V}_E$ BTPS at 180 P.R.	-0.01			
$\dot{V}_E$ BTPS at Recovery			-0.1	
$\dot{V}_E$ STPD at Rest				
$\dot{V}_E$ STPD at 25% Load				
$\dot{V}_E$ STPD at 50% Load				
$\dot{V}_E$ STPD at 75% Load		0.1		

TABLE IV..SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-STRESS....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
$\dot{V}_E$ STPD at 180 P.R.	-0.01			
$\dot{V}_E$ STPD at Recovery			-0.1	
Respiratory Rate at Rest				0.01
Respiratory Rate at 25% Load				0.05
Respiratory Rate at 50% Load			0.1	
Respiratory Rate at 75% Load		0.1		
Respiratory Rate at 180 P.R.	-0.01			
Respiratory Rate at Recovery				
Tidal Volume at Rest				
Tidal Volume at 25% Load				
Tidal Volume at 50% Load				-0.05
Tidal Volume at 75% Load	0.05	-0.1		-0.1
Tidal Volume at 180 P.R.			-0.05	
Tidal Volume at Recovery			-0.05	
$\dot{V}_{CO_2}$ at Rest				
$\dot{V}_{CO_2}$ at 25% Load				
$\dot{V}_{CO_2}$ at 50% Load				
$\dot{V}_{CO_2}$ at 75% Load	0.05			
$\dot{V}_{CO_2}$ at 180 P.R.	-0.001	-0.05	-0.001	
$\dot{V}_{CO_2}$ at Recovery			-0.01	
$\dot{V}_{O_2}$ at Rest				
$\dot{V}_{O_2}$ at 25% Load				
$\dot{V}_{O_2}$ at 50% Load				

TABLE IV..SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-STRESS....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
$\dot{V}_{O_2}$ at 75% Load			-0.1	
$\dot{V}_{O_2}$ at 180 P.R.	-0.001		-0.01	
$\dot{V}_{O_2}$ at Recovery			-0.1	
$\dot{V}_{O_2}$/pulse at Rest				
$\dot{V}_{O_2}$/pulse at 25% Load			-0.1	
$\dot{V}_{O_2}$/pulse at 50% Load	-0.05		-0.05	
$\dot{V}_{O_2}$/pulse at 75% Load				
$\dot{V}_{O_2}$/pulse at 180 P.R.	-0.001	-0.1	-0.01	
$\dot{V}_{O_2}$/pulse at Recovery			-0.05	
$\dot{V}_{O_2}$/kgbw·min at Rest				
$\dot{V}_{O_2}$/kgbw·min at 25% Load				
$\dot{V}_{O_2}$/kgbw·min at 50% Load				
$\dot{V}_{O_2}$/kgbw·min at 75% Load		0.1		
$\dot{V}_{O_2}$/kgbw at 180 P.R.	-0.001		-0.01	
$\dot{V}_{O_2}$/kgbw at Recovery			-0.1	
$\dot{V}_E/\dot{V}_{O_2}$ at Rest				0.05
$\dot{V}_E/\dot{V}_{O_2}$ at 25% Load				
$\dot{V}_E/\dot{V}_{O_2}$ at 50% Load				
$\dot{V}_E/\dot{V}_{O_2}$ at 75% Load				
$\dot{V}_E/\dot{V}_{O_2}$ at 180 P.R.	-0.05			
$\dot{V}_E/\dot{V}_{O_2}$ at Recovery				
Cardiac Output at Rest				
Cardiac Output at 25% Load				

TABLE IV..SIGNIFICANCE LEVELS OF CHANGES IN VARIABLES MEASURED PRE- AND POST-STRESS....CONTINUED

VARIABLE	GROUP			
	A	B	C	D
	Bed Rest	Quit Training	Sleep Deprivation	Control
Cardiac Output at 50% Load				
Cardiac Output at 75% Load				
Cardiac Output at Recovery				
Respiratory Exchange Ratio at Rest				
Respiratory Exchange Ratio at 25% Load				
Respiratory Exchange Ratio at 50% Load				
Respiratory Exchange Ratio at 75% Load				
Respiratory Exchange Ratio at 180 P.R.		-0.1	-0.05	
Respiratory Exchange Ratio at Recovery				

In Table III, it is apparent that the three groups which trained (Groups A, B, and C) increased in strength. Group A had five significant increases in strength variables. Group B had six significant increases and Group C had eight significant increases. In contrast, the control group (D) had no net changes in strength variables. Table IV indicates that the strength variables which were measured pre- and post-stress were not greatly affected by the specific stress which was inflicted. Each group had one significant decrease.

In Tables III and IV, no pattern emerges in the blood analyses and any interpretation would be difficult.

Some of the bicycle test variables are the best indicators of cardiopulmonary fitness. The group means for these variables for the seven bicycle ergometer tests are plotted in Figures 1-7 inclusive. These seven variables are Time on Bike, Pulse Rate at 75% Load, $\dot{V}_E$ BTPS at 180 P.R., $\dot{V}_{CO_2}$ at 180 P.R., $\dot{V}_{O_2}$ at 180 P.R., $\dot{V}_{O_2}$/pulse at 180 P.R., and $\dot{V}_{O_2}$/kgbw·min at 180 P.R. The three training

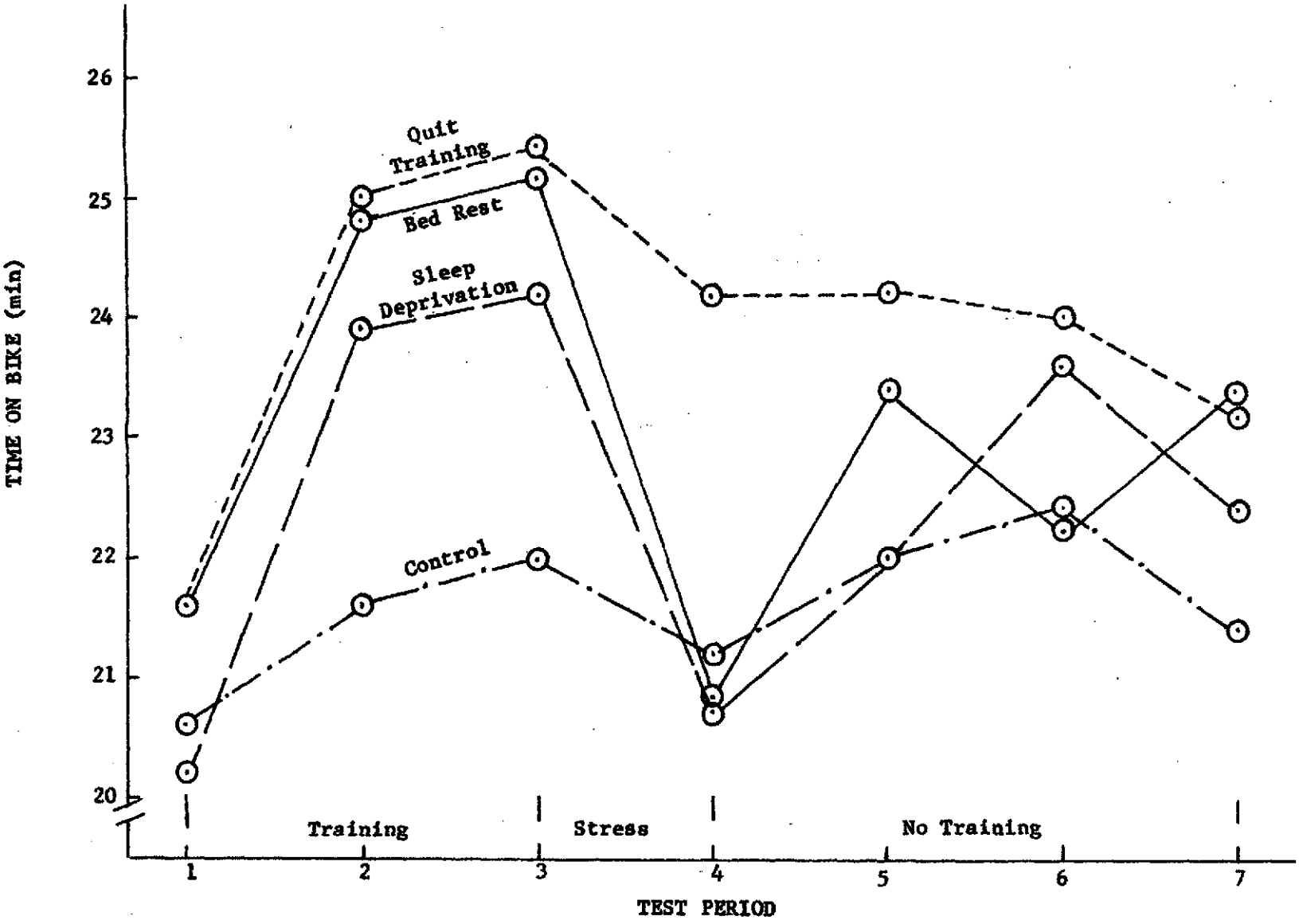


Figure 1. The mean time on the bicycle ergometer per test for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

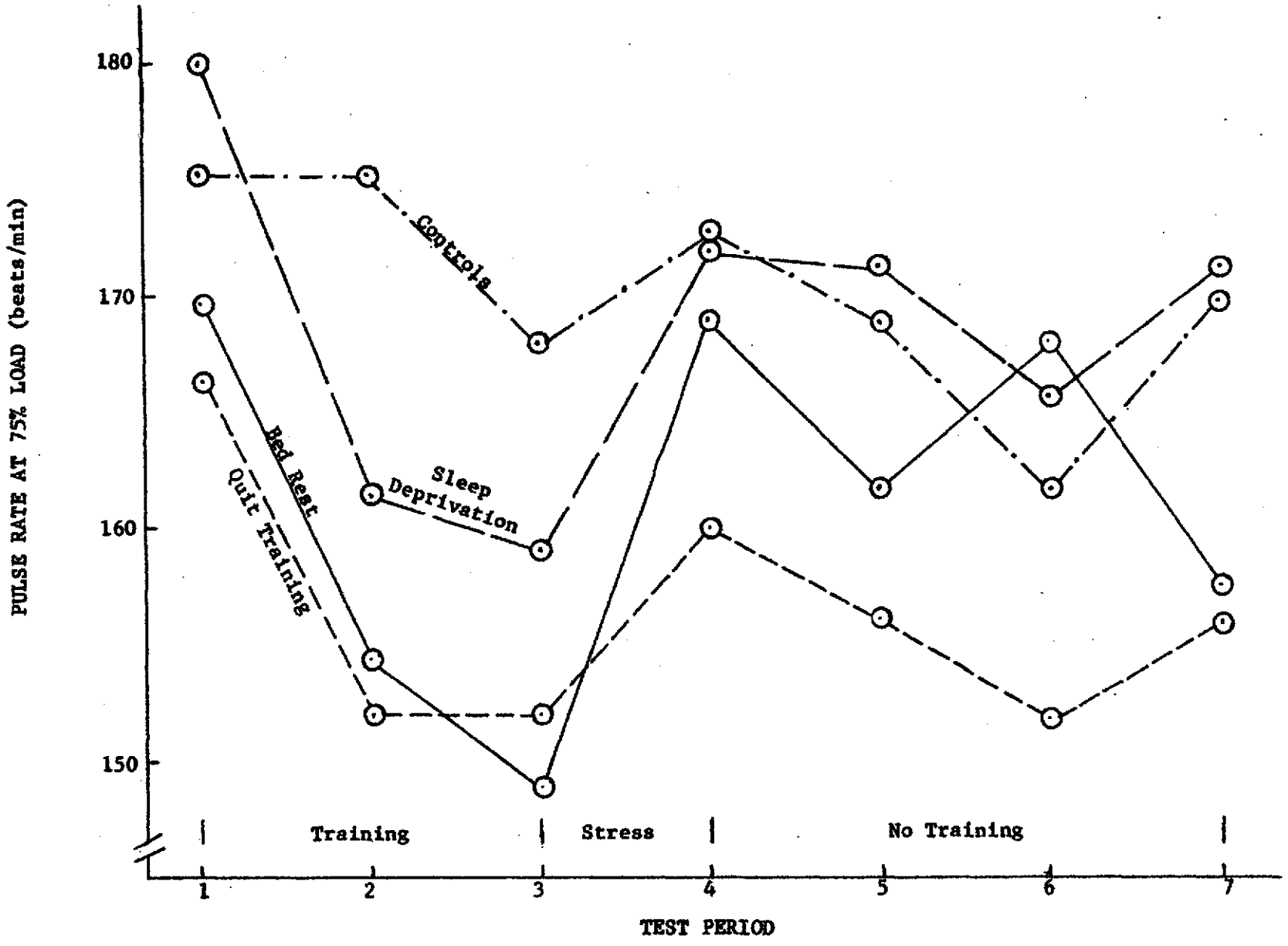


Figure 2. The mean pulse rate at a 75% work load for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

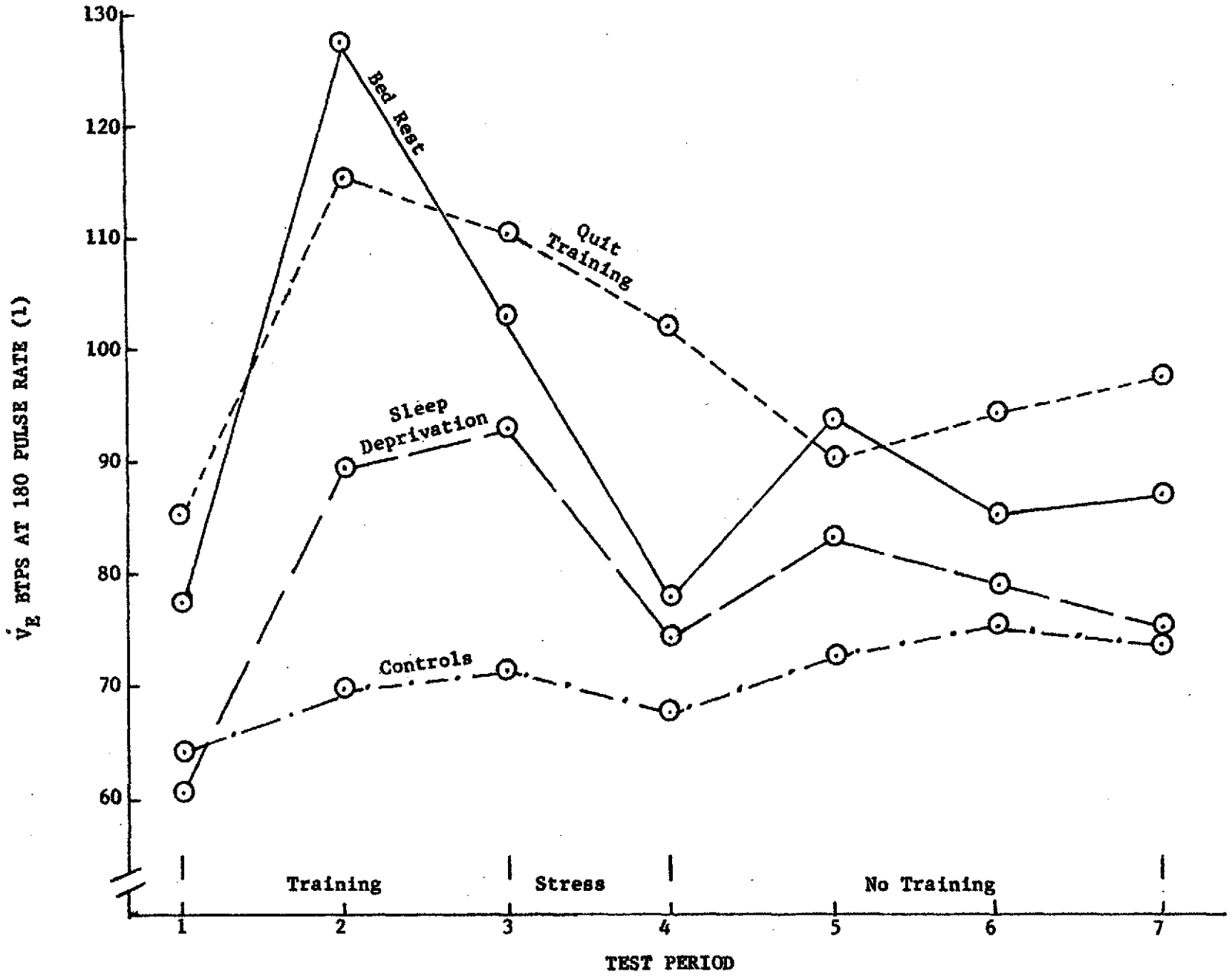


Figure 3. The $\dot{V}_E$ BTPS at 180 P.R. on the bicycle ergometer for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

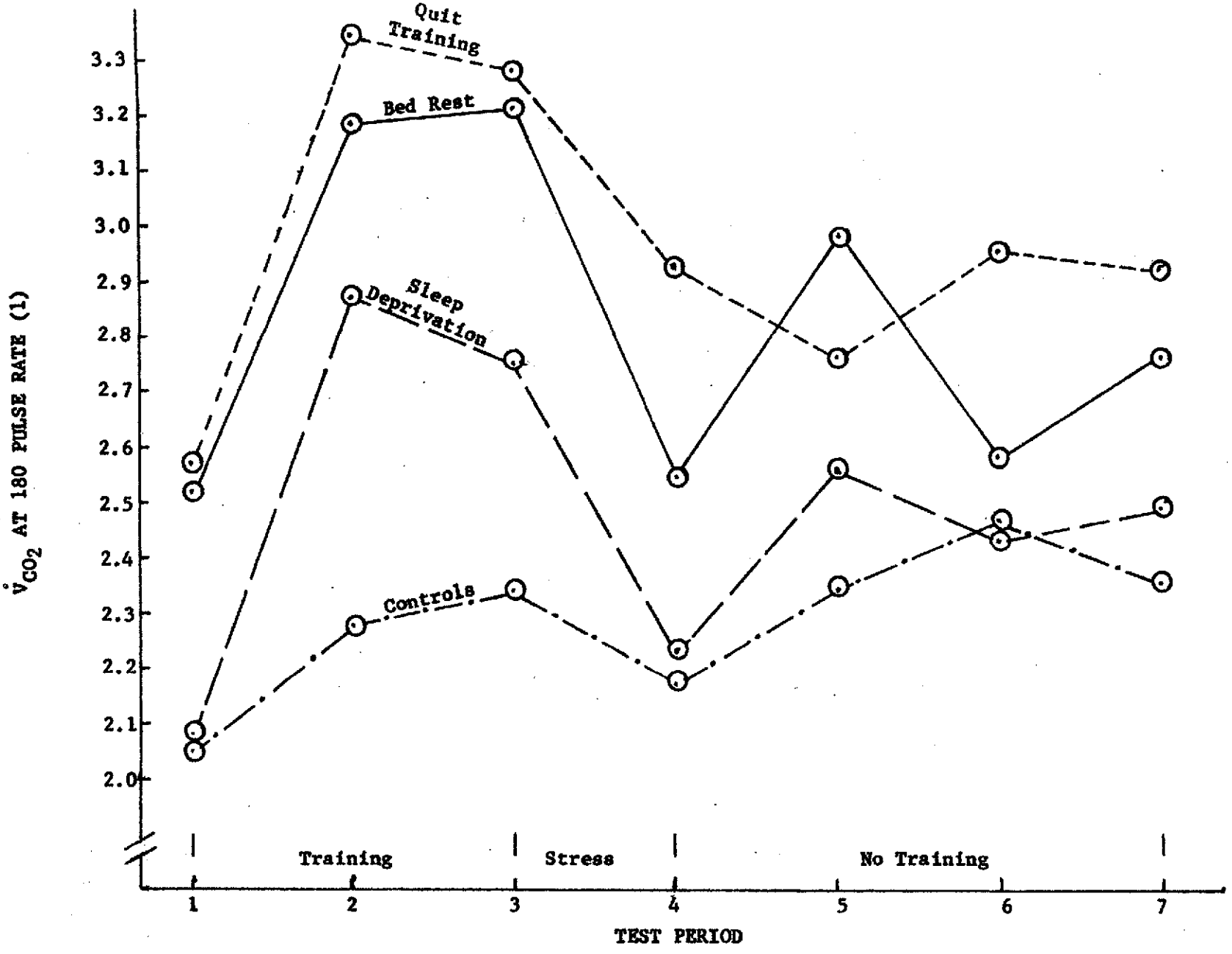


Figure 4. The $\dot{V}_{CO_2}$ at 180 P.R. on the bicycle ergometer for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

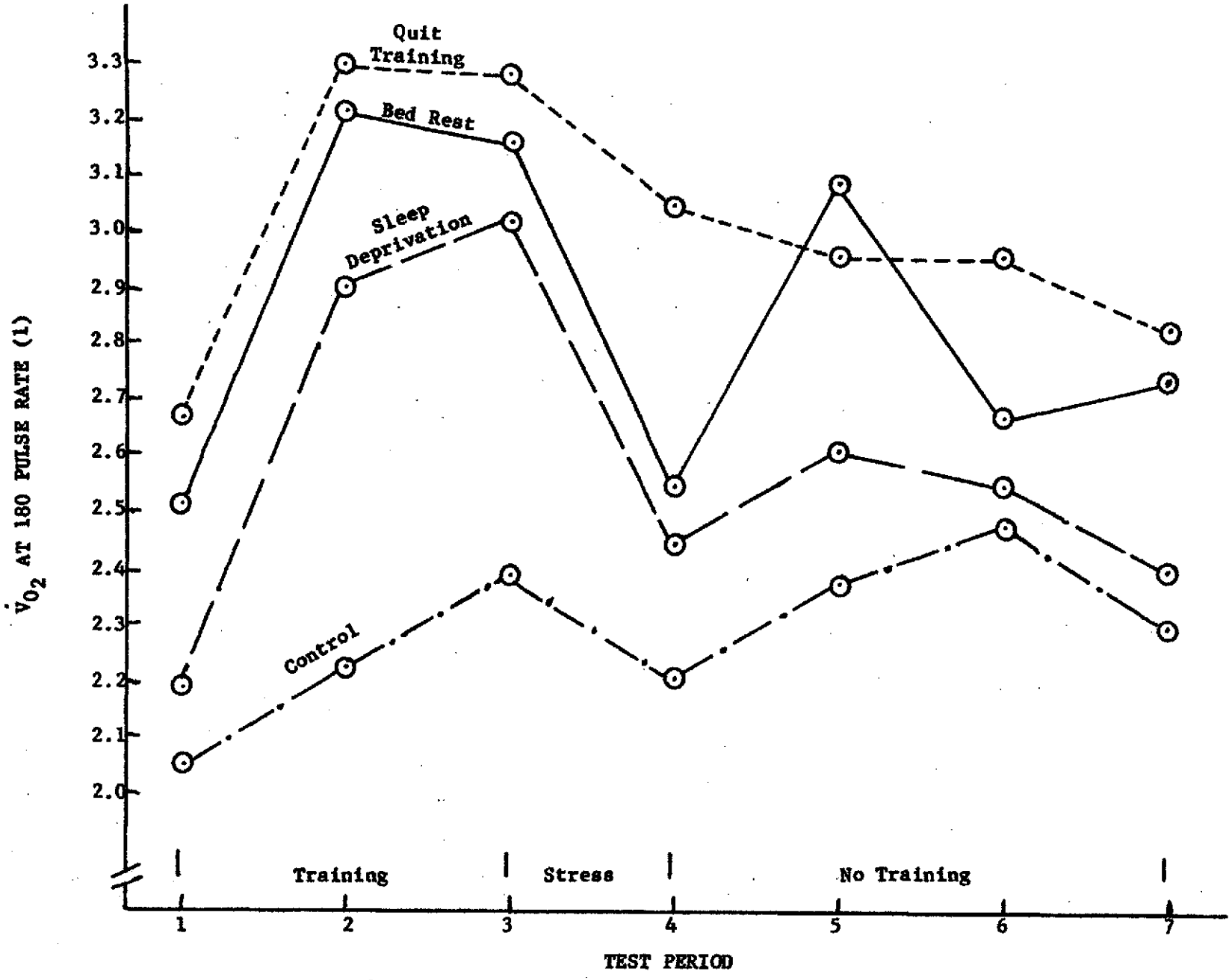


Figure 5. The mean $\dot{V}_{O_2}$ at 180 P.R. for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

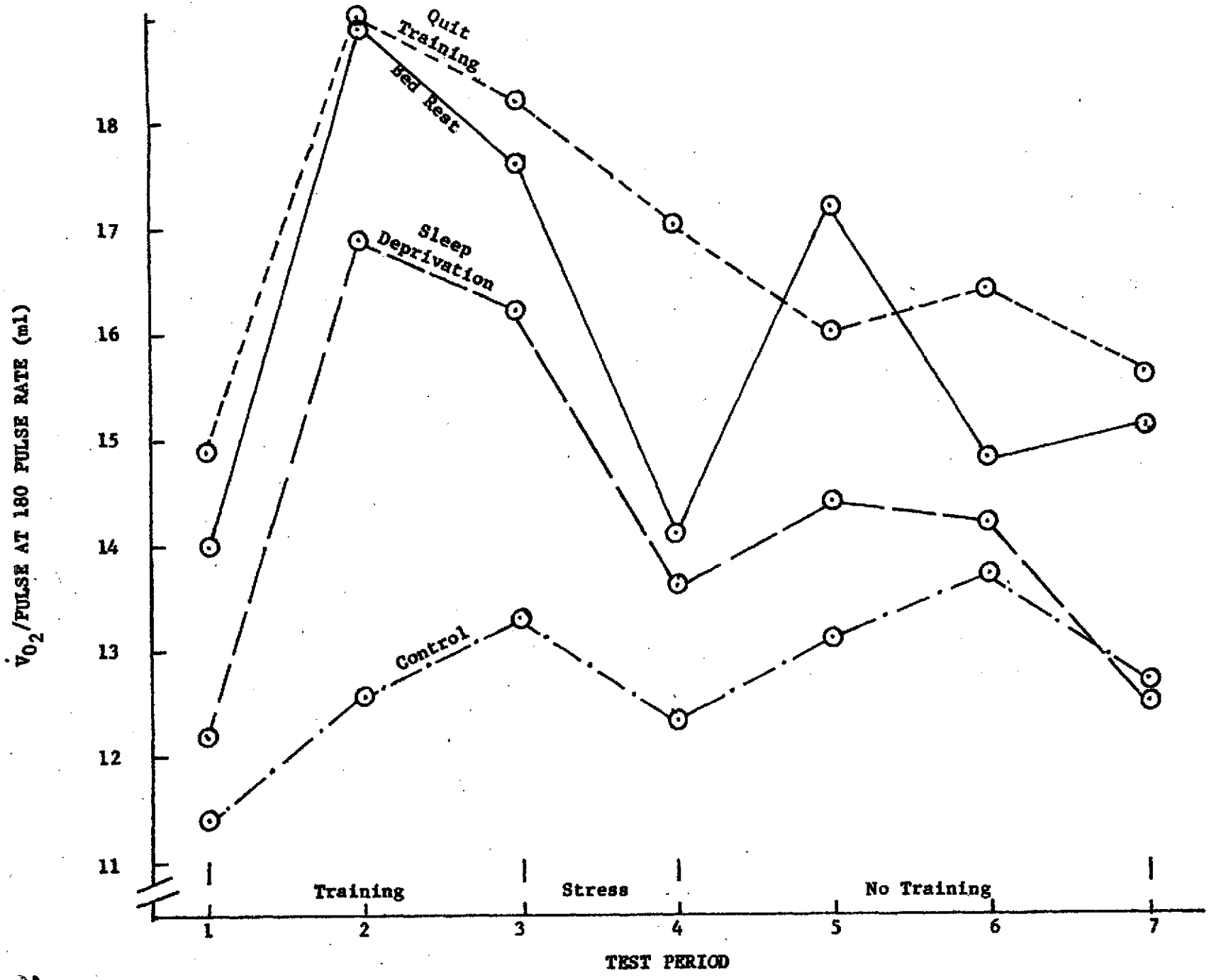


Figure 6. The $\dot{V}_{O_2}$/pulse at 180 P.R. on the bicycle ergometer for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

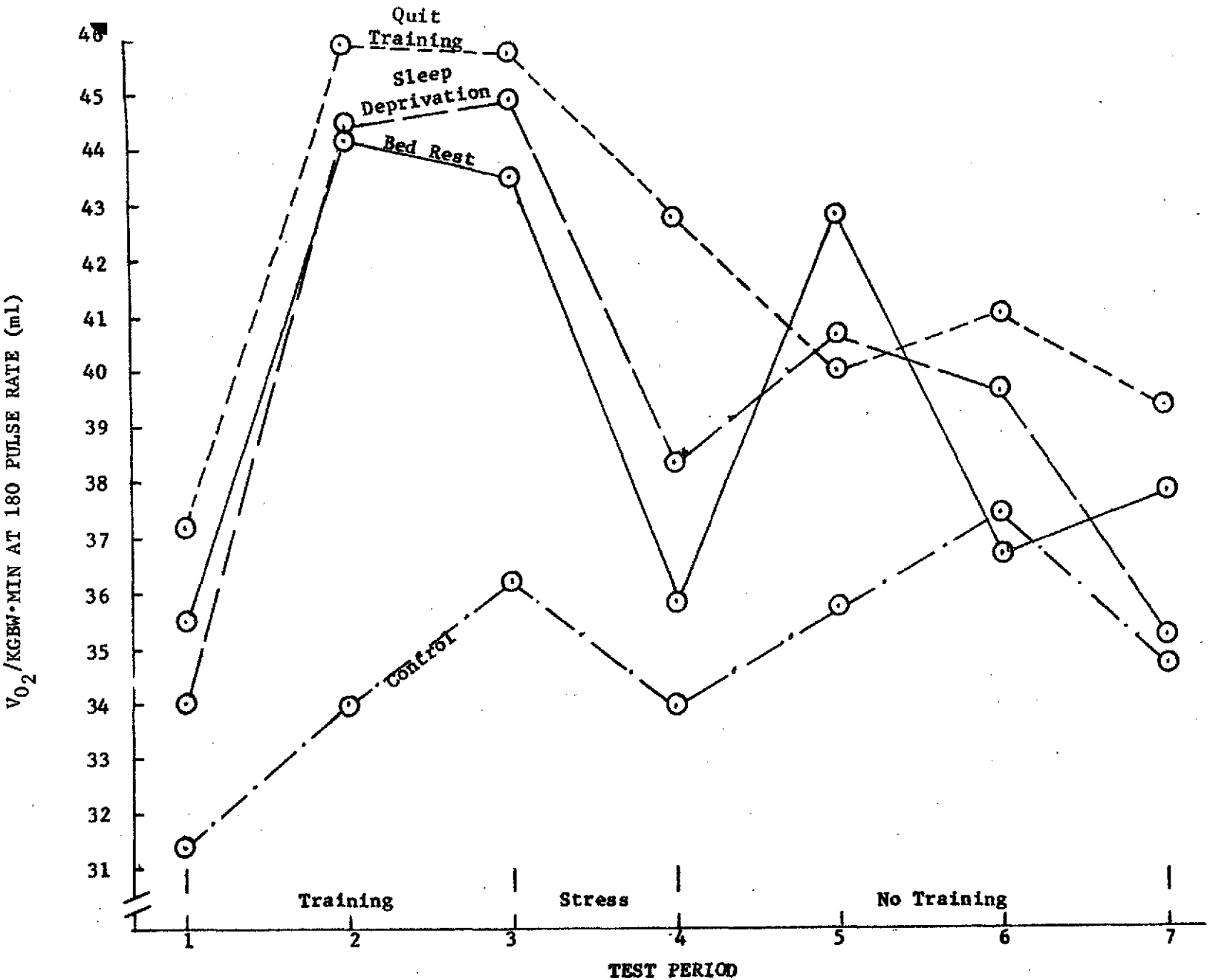


Figure 7. The $\dot{V}_{O_2}$/kgbw·min at 180 P.R. on the bicycle ergometer for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

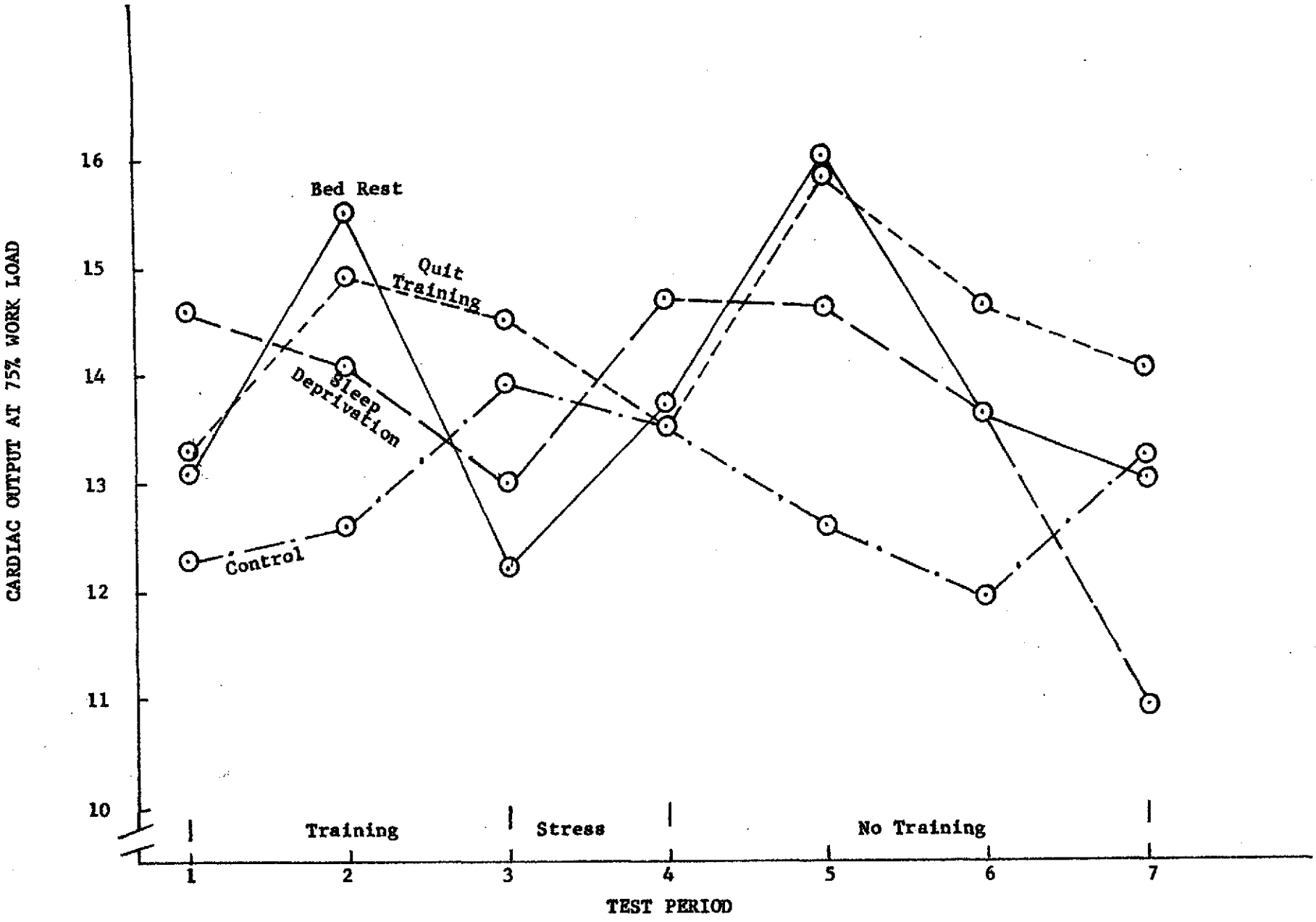


Figure 8. The cardiac output at a 75% work load for all groups throughout the experimental period. The "Control" group received no training or stress. The "Quit Training" group was not stressed other than discontinuance of training after test period three. Treated groups were trained for approximately thirteen weeks, stressed for one week or less, and received no training for the following six weeks.

groups (A, B, and C) showed highly significant changes in these variables, pre- versus post-training (Table III), which indicate increased cardiopulmonary fitness. The control group also showed significant changes for some of these variables but in general at a lower level of significance (Table III). When the pre- and post-stress values for these variables are contrasted, the two groups most severely stressed (A and C) exhibited the most significant changes (Table IV). For Group A all seven variables showed significant changes indicating decreased fitness post-stress (Table IV). For Group C six of the seven variables showed significant changes indicating decreased fitness post-stress (Table IV). Group B, whose only stress was a discontinuance of training, had three significant changes indicating decreased fitness post-stress while the control group had no significant changes in these seven variables (Table IV).

The curves for the group means plotted in Figures 1 and 3-7 inclusive are similar. Figure 1, Time on the Bike, is representative of the directional tendencies of the group curves in these figures during the experimental period and therefore it will be discussed in detail. The control curve fluctuates slightly but there are no sharp changes in slope. For the three groups which trained there is a substantial increase with training (test period 1 versus test period 3). With stress there is a precipitous drop for both the Bed Rest and Sleep Deprivation groups (test period 3 versus test period 4). As would be expected, the Quit Training group also showed a decrease but to a lesser degree (test period 3 versus test period 4). Remember that these decreases occurred within the span of one week or less. The Quit Training group continued to decline slowly for the next six weeks (test period 4 versus test period 7). For the two most severely stressed groups (Bed Rest and Quit Training), the means bounced back toward pre-stress levels during a two to four week period following stress (test periods 5 and 6) and then leveled off or decreased with some fluctuation for the remainder of the experimental period.

The curves in Figure 2 show the same general pattern as that discussed above but in the opposite direction. At a constant work level (75% of maximum pre-training work load) the pulse rate decreased with training and increased with deconditioning due to stress.

No significant changes in cardiac output were found under any of the conditions present in this experiment (Tables III and IV). There is no pattern to the changes in the cardiac output curves in Figure 8 and changes seem to be due to random variation. In retrospect, maybe this result should have been expected. When the work load is held constant, a constant amount of energy must be expended to perform at that level. A constant amount of oxygen would be required to generate that energy, and if the efficiency of the respiratory system does not change, a constant volume of blood must be supplied to the muscle. It therefore seems logical, assuming no significant change in the efficiency of the respiratory system, that there will be negligible change in cardiac output unless the work load is changed and that this is true irregardless of the fitness of the subject. Cardiac output is the product of the pulse rate and the stroke volume. Figure 2 shows that the pulse rate declines with training when the work load is held constant. Since cardiac output remains relatively constant at a constant work load, the stroke volume must increase with training.

Figure 6 shows that $\dot{V}_{O_2}$/pulse increases with training. This could be due to either or both of two factors, increased efficiency of the respiratory system and/or increased volume of blood per pulse, i.e., stroke volume. A change in the respiratory efficiency would produce a change in the opposite direction in the cardiac output. Since cardiac output and O_2 uptake remain relatively constant for a given work load it appears that the respiratory efficiency also remains relatively constant. If the procedure we are using to estimate cardiac output is valid, stroke volume is the variable that is significantly changing to compensate for the changing pulse rate to maintain a constant cardiac output.

It is our subjective impression, after calculating 700 cardiac outputs, that this procedure lacks precision. The precision may well vary with the quality of the single breath curve that is obtained and the location of the points on the curve.

It is also apparent from Figure 2 that there is a dramatic rise in pulse rate at a constant work load associated with deconditioning due to stress. This means that deconditioning due to stress results in a dramatic decrease in stroke volume.

Table V contains the mean pre- and post-training values of all the variables that were measured. Table VI contains the mean pre- and post-stress values of all the variables that were measured.

V. Conclusions

1. There was a moderate increase in strength variables due to the training in this experiment but the stress which the subjects received caused a negligible change in strength variables.

2. The training program in this experiment resulted in highly significant changes in specific bicycle ergometer variables indicating good increases in cardiopulmonary fitness. Five days of bed rest or fifty hours of sleep deprivation caused comparable drastic decreases in cardiopulmonary fitness. Post stress the subjects reverted to a normal daily schedule and after two weeks they had recovered about half of what they lost.

3. Cardiac output remains relatively constant at a constant work load but stroke volume increases with conditioning and decreases with deconditioning due to stress.

TABLE V

MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
ANTHROPOMETRIC MEASUREMENTS					
Neck (cm)	Pre	36.56	36.44	35.24	35.34
	Post	36.92	36.38	35.38	35.20
	Difference	0.36	-0.06	0.14	-0.14
Chest (cm)	Pre	95.88	95.52	89.26	92.22
	Post	97.92	95.42	89.48	93.18
	Difference	2.04	-0.10	0.22	0.96
Left Bicep (cm)	Pre	30.86	31.28	29.38	29.84
	Post	31.82	31.96	29.90	30.38
	Difference	0.96	0.68	0.52	0.54
Right Bicep (cm)	Pre	31.58	32.66	30.00	30.62
	Post	32.68	33.32	30.48	31.74
	Difference	1.10	0.66	0.48	1.12
Left Forearm (cm)	Pre	26.50	26.10	24.90	25.94
	Post	26.92	26.42	25.40	26.10
	Difference	0.42	0.32	0.50	0.16
Right Forearm (cm)	Pre	27.08	26.78	25.38	26.26
	Post	27.42	26.96	25.64	26.28
	Difference	0.34	0.18	0.26	0.02
Waist (cm)	Pre	77.68	77.44	72.94	75.14
	Post	79.24	76.74	71.94	75.60
	Difference	1.56	-0.70	-1.00	0.46
Left Thigh (cm)	Pre	53.14	54.74	51.96	50.78
	Post	54.06	54.46	51.74	50.70
	Difference	0.92	-0.28	-0.22	-0.08
Right Thigh (cm)	Pre	53.38	55.24	51.96	50.46
	Post	54.42	55.22	51.20	51.00
	Difference	1.04	-0.02	-0.76	0.54

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Left Calf (cm)	Pre	36.38	36.70	36.74	34.34
	Post	36.80	36.62	36.48	34.28
	Difference	0.42	-0.08	-0.26	-0.06
Right Calf (cm)	Pre	37.02	36.84	36.52	34.72
	Post	37.42	36.78	36.52	34.54
	Difference	0.40	-0.06	0.00	-0.18
STRENGTH MEASUREMENTS Pullups	Pre	8.6	5.4	5.6	8.8
	Post	11.0	8.2	8.2	11.2
	Difference	2.4	2.8	2.6	2.4
Dips	Pre	16.4	16.6	14.0	17.6
	Post	18.8	19.6	19.4	16.0
	Difference	2.4	3.0	5.4	-1.6
Arm Strength	Pre	594.4	531.6	405.0	623.8
	Post	724.6	677.2	566.8	652.2
	Difference	130.2	145.6	161.8	28.4
Left Hand Grip (lbs)	Pre	126.4	113.6	102.0	108.8
	Post	129.2	107.6	103.6	114.0
	Difference	2.8	-6.0	1.6	5.2
Right Hand Grip (lbs)	Pre	133.2	124.8	113.2	126.8
	Post	134.0	122.8	110.8	135.2
	Difference	0.8	-2.0	-2.4	8.4
Leg Lift (lbs)	Pre	1113	1431	1084	1096
	Post	1176	1452	1245	974
	Difference	63	21	161	-122
Back Lift (lbs)	Pre	407	374	356	370
	Post	408	374	368	351
	Difference	1	0	12	-19
Strength Index	Pre	2691	2872	2329	2634
	Post	2895	3029	2662	2532
	Difference	204	157	333	-102
Physical Fitness Index	Pre	100	102	96	104
	Post	104	108	110	98
	Difference	4	6	14	-6

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Shoulder Extension (lbs)	Pre	150	145	125	159
	Post	166	153	130	143
	Difference	17	8	5	-16
Knee Extension (lbs)	Pre	285	287	271	304
	Post	295	294	286	310
	Difference	10	7	15	6
Ankle Plantar Flexion (lbs)	Pre	326	312	301	292
	Post	374	318	333	280
	Difference	48	6	32	-12
Strength Quotient	Pre	1.062	1.124	1.136	1.232
	Post	1.198	1.254	1.306	1.164
	Difference	0.136	0.130	0.170	-0.068
PHYSIOLOGICAL VARIABLES					
Weight (kg)	Pre	70.70	71.78	64.42	66.44
	Post	72.46	71.60	64.10	67.34
	Difference	1.76	-0.18	-0.32	0.90
Vital Capacity (l)	Pre	5.20	4.86	4.40	5.06
	Post	5.30	4.84	4.38	5.00
	Difference	0.10	-0.02	-0.02	-0.06
BLOOD ANALYSES					
Protein (mg %)	Pre	7.3	7.2	7.3	7.2
	Post	7.1	7.2	7.3	7.3
	Difference	-0.2	0.0	0.0	0.1
Glucose (mg %)	Pre	90.8	92.7	87.8	86.1
	Post	91.1	87.1	84.0	88.7
	Difference	0.3	-5.6	-3.8	2.6
Total Lipids (mg %)	Pre	482	606	522	519
	Post	369	564	494	499
	Difference	-113	-42	-28	-20
Cholesterol (mg %)	Pre	153	192	167	165
	Post	134	189	151	152
	Difference	-19	-3	-16	-13

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Triglycerides (mg %)	Pre	90	86	110	84
	Post	76	85	67	63
	Difference	-14	-1	-43	-21
Phospholipids (mg %)	Pre	193	217	203	190
	Post	194	199	244	163
	Difference	1	-18	41	-27
Na^{+} (meq/l)	Pre	145	144	147	145
	Post	145	147	147	143
	Difference	0	3	0	-2
K^{+} (meq/l)	Pre	4.0	4.3	4.2	4.2
	Post	5.3	5.2	5.5	4.9
	Difference	1.3	0.9	1.3	0.7
Ca^{+2} (meq/l)	Pre	6.0	5.8	6.0	6.1
	Post	6.0	5.7	5.6	5.2
	Difference	0.0	-0.1	-0.4	-0.9
BICYCLE TEST VARIABLES					
Time on Bike (1 min)	Pre	21.6	21.6	20.2	20.6
	Post	25.2	25.4	24.2	22.0
	Difference	3.6	3.8	4.0	1.4
Systolic Blood Pressure at Rest (mm Hg)	Pre	132	120	126	132
	Post	126	126	126	121
	Difference	-6	6	0	-11
Systolic Blood Pressure at 25% Load (mm Hg)	Pre	149	140	160	145
	Post	144	142	147	141
	Difference	-5	2	-13	-4
Systolic Blood Pressure at 50% Load (mm Hg)	Pre	166	154	177	166
	Post	158	168	166	159
	Difference	-8	14	-11	-7
Systolic Blood Pressure at 75% Load (mm Hg)	Pre	183	172	190	173
	Post	180	181	184	177
	Difference	-3	9	-6	4
Systolic Blood Pressure at 180 P.R. (mm Hg)	Pre	180	180	186	170
	Post	205	193	197	180
	Difference	25	13	11	10

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Systolic Blood Pressure at Recovery (mm Hg)	Pre	143	138	138	142
	Post	142	150	150	138
	Difference	-1	12	12	-4
Diastolic Blood Pressure at Rest (mm Hg)	Pre	81	73	76	76
	Post	78	74	74	76
	Difference	-3	1	-2	0
Diastolic Blood Pressure at 25% Load (mm Hg)	Pre	74	70	74	74
	Post	68	69	67	74
	Difference	-6	-1	-7	0
Diastolic Blood Pressure at 50% Load (mm Hg)	Pre	70	68	69	69
	Post	64	68	64	73
	Difference	-6	0	-5	4
Diastolic Blood Pressure at 75% Load (mm Hg)	Pre	62	66	65	67
	Post	63	63	65	69
	Difference	1	-3	0	2
Diastolic Blood Pressure at 180 P.R. (mm Hg)	Pre	63	62	66	67
	Post	61	61	62	62
	Difference	-2	-1	-4	-5
Diastolic Blood Pressure at Recovery (mm Hg)	Pre	78	70	79	76
	Post	70	68	75	70
	Difference	-8	-2	-4	-6
Pulse Rate at Rest (beats/min.)	Pre	79.2	84.0	86.4	91.2
	Post	76.8	77.6	77.6	80.8
	Difference	-2.4	-6.4	-8.8	-10.4
Pulse Rate at 25% Load (beats/min.)	Pre	108.8	114.4	122.4	122.4
	Post	104.8	103.2	107.2	106.4
	Difference	-4.0	-11.2	-15.2	-16.0
Pulse Rate at 50% Load (beats/min.)	Pre	139.2	138.4	152.0	150.4
	Post	124.8	124.8	130.4	139.2
	Difference	-14.4	-13.6	-21.6	-11.2
Pulse Rate at 75% Load (beats/min.)	Pre	169.6	166.4	180.0	175.2
	Post	148.8	152.0	159.2	168.0
	Difference	-20.8	-14.4	-20.8	-7.2

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Pulse Rate at 180 (beats/min.)	Pre	180.0	180.0	179.2	179.2
	Post	180.0	180.0	178.4	179.2
	Difference	0.0	0.0	-0.8	0.0
Pulse Rate at Recovery (beats/min.)	Pre	113.6	105.6	116.8	117.6
	Post	106.4	116.0	109.6	104.8
	Difference	-7.2	10.4	-7.2	-12.8
$\dot{V}_E$ BTPS at Rest (l)	Pre	14.2	11.2	12.2	14.0
	Post	12.8	13.2	15.2	18.0
	Difference	-1.4	2.0	3.0	4.0
$\dot{V}_E$ BTPS at 25% Load (l)	Pre	27.0	28.0	24.4	31.2
	Post	28.4	28.0	29.8	29.8
	Difference	1.4	0.0	5.4	-1.4
$\dot{V}_E$ BTPS at 50% Load (l)	Pre	45.8	44.2	45.2	40.4
	Post	44.4	40.8	43.4	41.2
	Difference	-1.4	-2.4	-1.8	0.8
$\dot{V}_E$ BTPS at 75% Load (l)	Pre	65.2	66.0	62.0	63.4
	Post	61.0	60.0	62.2	61.6
	Difference	-4.2	-6.0	0.2	-1.8
$\dot{V}_E$ BTPS at 180 P.R. (l)	Pre	77.4	85.2	60.6	64.0
	Post	103.0	110.4	92.8	71.6
	Difference	25.6	25.2	32.2	7.6
$\dot{V}_E$ BTPS at Recovery (l)	Pre	22.6	21.2	17.6	21.6
	Post	23.4	26.0	24.0	19.2
	Difference	0.8	4.8	6.4	-2.4
$\dot{V}_E$ STPD at Rest (l)	Pre	11.4	9.2	10.0	11.6
	Post	10.6	10.6	12.6	15.0
	Difference	-0.8	1.4	2.6	3.4
$\dot{V}_E$ STPD at 25% Load (l)	Pre	22.2	23.2	20.2	26.0
	Post	23.8	23.4	25.0	24.8
	Difference	1.6	0.2	4.8	-1.2
$\dot{V}_E$ STPD at 50% Load (l)	Pre	37.8	36.8	37.2	33.6
	Post	37.0	34.0	36.2	34.2
	Difference	-0.8	-2.8	-1.0	0.6

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_E$ STPD at 75% Load (l)	Pre	54.0	54.8	51.2	52.4
	Post	50.8	50.0	51.8	51.6
	Difference	-3.2	4.8	0.6	-0.8
$\dot{V}_E$ STPD at 180 P.R. (l)	Pre	64.4	71.0	50.4	53.0
	Post	86.2	91.4	73.6	59.8
	Difference	21.8	20.4	23.2	6.8
$\dot{V}_E$ STPD at Recovery (l)	Pre	18.6	17.4	15.0	18.0
	Post	19.8	21.8	20.2	16.2
	Difference	1.2	4.4	5.2	-1.8
Respiratory Rate at Rest (breaths/min.)	Pre	18.0	11.4	13.6	11.4
	Post	16.0	12.0	13.2	11.2
	Difference	-2.0	0.6	-0.4	-0.2
Respiratory Rate at 25% Load (breaths/min.)	Pre	25.4	20.4	20.4	21.6
	Post	21.6	19.2	23.0	18.0
	Difference	-3.8	-1.2	2.6	-3.6
Respiratory Rate at 50% Load (breaths/min.)	Pre	27.4	21.6	26.2	20.4
	Post	23.6	21.6	24.0	20.2
	Difference	-3.8	0.0	-2.2	-0.2
Respiratory Rate at 75% Load (breaths/min.)	Pre	33.2	31.6	30.6	31.8
	Post	28.4	24.6	32.4	26.4
	Difference	-4.8	-7.0	1.8	-5.4
Respiratory Rate at 180 P.R. (breaths/min.)	Pre	35.8	38.4	31.8	30.6
	Post	37.4	39.4	41.6	33.4
	Difference	1.6	1.0	9.8	2.8
Respiratory Rate at Recovery (breaths/min.)	Pre	21.8	14.8	15.6	13.2
	Post	19.2	20.0	17.4	16.2
	Difference	-2.6	5.2	1.8	3.0
Tidal Volume at Rest (l)	Pre	0.84	1.00	1.00	1.22
	Post	0.78	1.12	1.12	1.76
	Difference	-0.06	0.12	0.12	0.54
Tidal Volume at 25% Load (l)	Pre	1.08	1.42	1.18	1.66
	Post	1.34	1.48	1.36	1.90
	Difference	0.26	0.06	0.18	0.24

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Tidal Volume at 50% Load (1)	Pre	1.66	2.06	1.72	2.18
	Post	1.90	1.94	1.82	2.48
	Difference	0.24	-0.12	0.10	0.30
Tidal Volume at 75% Load (1)	Pre	2.02	2.14	2.06	2.12
	Post	2.16	2.44	1.98	2.62
	Difference	0.14	0.30	-0.08	0.50
Tidal Volume at 180 P.R. (1)	Pre	2.26	2.26	1.94	2.28
	Post	2.80	2.68	2.14	2.32
	Difference	0.54	0.42	0.20	0.04
Tidal Volume at Recovery (1)	Pre	1.12	1.50	1.18	1.86
	Post	1.22	1.32	1.48	1.38
	Difference	0.10	-0.18	0.30	-0.48
$\dot{V}_{CO_2}$ at Rest (1)	Pre	0.324	0.267	0.344	0.344
	Post	0.299	0.304	0.371	0.452
	Difference	-0.025	0.037	0.027	0.108
$\dot{V}_{CO_2}$ at 25% Load (1)	Pre	0.776	0.849	0.809	0.899
	Post	0.831	0.847	0.909	0.903
	Difference	0.055	-0.002	0.100	0.004
$\dot{V}_{CO_2}$ at 50% Load (1)	Pre	1.506	1.528	1.556	1.347
	Post	1.451	1.384	1.425	1.421
	Difference	-0.055	-0.144	-0.131	0.074
$\dot{V}_{CO_2}$ at 75% Load (1)	Pre	2.185	2.112	2.174	2.018
	Post	2.029	2.073	2.045	2.083
	Difference	-0.156	-0.039	-0.129	0.065
$\dot{V}_{CO_2}$ at 180 P.R. (1)	Pre	2.523	2.571	2.079	2.048
	Post	3.215	3.278	2.753	2.342
	Difference	0.692	0.707	0.674	0.294
$\dot{V}_{CO_2}$ at Recovery (1)	Pre	0.520	0.531	0.468	0.528
	Post	0.540	0.606	0.593	0.471
	Difference	0.020	0.075	0.125	-0.057
$\dot{V}_{O_2}$ at Rest (1)	Pre	0.352	0.316	0.393	0.370
	Post	0.309	0.337	0.391	0.447
	Difference	-0.043	0.021	-0.002	0.077

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_{O_2}$ at 25% Load (l)	Pre	0.921	1.026	0.982	0.990
	Post	0.958	0.983	1.096	0.992
	Difference	0.037	-0.043	0.114	0.002
$\dot{V}_{O_2}$ at 50% Load (l)	Pre	1.609	1.681	1.687	1.437
	Post	1.586	1.543	1.608	1.507
	Difference	-0.023	-0.138	-0.079	0.070
$\dot{V}_{O_2}$ at 75% Load (l)	Pre	2.212	2.352	2.273	2.066
	Post	2.130	2.189	2.247	2.113
	Difference	-0.082	-0.163	-0.026	0.047
$\dot{V}_{O_2}$ at 180 P.R. (l)	Pre	2.516	2.675	2.189	2.049
	Post	3.159	3.276	3.024	2.390
	Difference	0.643	0.601	0.835	0.341
$\dot{V}_{O_2}$ at Recovery (l)	Pre	0.506	0.570	0.487	0.518
	Post	0.544	0.634	0.595	0.487
	Difference	0.038	0.064	0.108	-0.031
$\dot{V}_{O_2}$/Pulse at Rest (l)	Pre	4.50	4.72	4.62	4.14
	Post	4.08	4.60	5.32	5.44
	Difference	-0.42	0.88	0.70	1.30
$\dot{V}_{O_2}$/Pulse at 25% Load (l)	Pre	8.62	8.98	8.06	8.18
	Post	9.22	9.64	10.38	9.42
	Difference	0.60	0.66	2.32	1.24
$\dot{V}_{O_2}$/Pulse at 50% Load (l)	Pre	11.58	12.16	11.14	9.68
	Post	12.78	12.42	12.42	10.96
	Difference	1.20	0.26	1.28	1.28
$\dot{V}_{O_2}$/Pulse at 75% Load (l)	Pre	13.04	14.12	12.66	11.90
	Post	14.38	14.44	14.14	12.66
	Difference	1.34	0.32	1.48	0.76
$\dot{V}_{O_2}$/Pulse at 180 P.R. (l)	Pre	13.96	14.86	12.20	11.40
	Post	17.56	18.20	16.20	13.30
	Difference	3.60	3.34	4.00	1.90
$\dot{V}_{O_2}$/Pulse at Recovery (l)	Pre	4.48	5.32	4.16	4.48
	Post	5.12	5.52	5.52	4.74
	Difference	0.64	0.20	1.36	0.26

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_{O_2}$/kgbw·min. at Rest (ml)	Pre	4.96	4.36	6.12	5.48
	Post	4.30	4.70	6.14	6.60
	Difference	-0.66	0.34	0.02	1.12
$\dot{V}_{O_2}$/kgbw·min. at 25% Load (ml)	Pre	13.14	14.24	15.26	14.88
	Post	13.24	13.72	17.04	14.88
	Difference	0.10	-0.52	1.78	0.00
$\dot{V}_{O_2}$/kgbw·min. at 50% Load (ml)	Pre	22.76	23.50	26.20	21.80
	Post	21.90	21.58	25.02	22.56
	Difference	-0.86	-1.92	-1.18	0.76
$\dot{V}_{O_2}$/kgbw·min at 75% Load (ml)	Pre	31.28	32.84	35.32	31.42
	Post	29.44	30.58	34.98	31.78
	Difference	-1.84	-2.26	-0.34	0.36
$\dot{V}_{O_2}$/kgbw·min. at 180 P.R. (ml)	Pre	35.46	37.22	33.90	31.44
	Post	43.46	45.74	44.94	36.16
	Difference	8.00	8.52	11.04	4.72
$\dot{V}_{O_2}$/kgbw·min. at Recovery (ml)	Pre	7.14	7.88	7.60	7.90
	Post	7.50	8.86	9.28	7.36
	Difference	0.36	0.98	1.68	-0.54
$\dot{V}_E/\dot{V}_{O_2}$ at Rest (1)	Pre	39.92	36.94	30.98	36.84
	Post	41.76	39.70	37.40	38.86
	Difference	1.84	2.76	6.42	2.02
$\dot{V}_E/\dot{V}_{O_2}$ at 25% Load (1)	Pre	29.16	27.06	25.12	30.98
	Post	30.08	28.36	27.68	29.84
	Difference	0.92	1.30	2.56	-1.14
$\dot{V}_E/\dot{V}_{O_2}$ at 50% Load (1)	Pre	28.36	26.28	26.82	28.10
	Post	28.22	26.32	27.42	27.14
	Difference	-0.14	0.04	0.60	-0.96
$\dot{V}_E/\dot{V}_{O_2}$ at 75% Load (1)	Pre	29.40	27.88	27.38	30.64
	Post	28.78	27.26	28.04	29.12
	Difference	-0.62	-0.62	0.66	-1.52
$\dot{V}_E/\dot{V}_{O_2}$ at 180 P.R. (1)	Pre	30.80	31.54	27.78	31.72
	Post	32.60	33.48	30.58	30.76
	Difference	1.80	1.94	2.80	-0.96

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	GROUP B Quit Training	GROUP C Sleep Deprivation	GROUP D Control
$\dot{V}_E/\dot{V}_{O_2}$ at Recovery (1)	Pre	44.26	38.32	37.00	42.00
	Post	43.34	41.06	41.24	39.40
	Difference	-0.92	2.74	4.24	-2.60
Cardiac Output at Rest (l/min.)	Pre	5.14	3.76	6.10	4.90
	Post	4.32	3.50	6.02	5.32
	Difference	-0.82	-0.26	-0.08	0.42
Cardiac Output at 25% Load (l/min.)	Pre	8.12	8.24	9.34	9.06
	Post	8.32	8.84	10.06	8.80
	Difference	0.20	0.60	0.72	-0.26
Cardiac Output at 50% Load (l/min.)	Pre	12.22	12.02	13.00	10.54
	Post	11.12	12.16	12.86	11.00
	Difference	-1.10	0.14	-0.14	0.46
Cardiac Output at 75% Load (l/min.)	Pre	13.10	13.34	14.56	12.30
	Post	12.18	14.52	13.00	13.88
	Difference	-0.92	1.18	-1.56	1.58
Cardiac Output at Recovery (l/min.)	Pre	8.52	7.46	7.82	7.40
	Post	9.14	8.24	8.28	8.40
	Difference	0.62	0.78	0.46	1.00
Respiratory Exchange Ratio at Rest	Pre	0.912	0.860	0.872	0.908
	Post	0.958	0.898	0.916	0.982
	Difference	0.046	0.038	0.044	0.074
Respiratory Exchange Ratio at 25% Load	Pre	0.842	0.824	0.826	0.904
	Post	0.866	0.856	0.828	0.902
	Difference	0.024	0.032	0.002	-0.002
Respiratory Exchange Ratio at 50% Load	Pre	0.938	0.906	0.922	0.938
	Post	0.916	0.898	0.888	0.942
	Difference	-0.022	-0.008	-0.034	0.004
Respiratory Exchange Ratio at 75% Load	Pre	0.986	0.900	0.958	0.980
	Post	0.958	0.948	0.912	0.982
	Difference	-0.028	0.048	-0.046	0.002

TABLE V... MEAN PRE- AND POST-TRAINING VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Depriv-ation	D Control
Respiratory Exchange Ratio at 180 P.R.	Pre	1.000	0.964	0.950	0.986
	Post	1.016	1.000	0.952	0.982
	Difference	0.016	0.036	0.002	-0.004
Respiratory Exchange Ratio at Recovery	Pre	1.016	0.952	0.968	1.022
	Post	0.990	0.954	0.994	0.966
	Difference	-0.026	0.002	0.026	-0.056

TABLE VI

MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
STRENGTH MEASUREMENTS					
Shoulder Extension (lbs)	Pre	166	153	130	143
	Post	156	142	120	135
	Difference	-10	-11	-10	-8
Knee Extension (lbs)	Pre	295	294	286	310
	Post	284	314	259	269
	Difference	-11	20	-27	-41
Ankle Plantar Flexion (lbs)	Pre	374	318	333	280
	Post	352	338	317	300
	Difference	-22	20	-16	20
Strength Quotient	Pre	1.198	1.254	1.306	1.164
	Post	1.134	1.298	1.210	1.110
	Difference	-0.064	0.044	-0.096	-0.054
BLOOD ANALYSES					
Protein (mg %)	Pre	7.1	7.2	7.2	7.3
	Post	6.6	7.3	7.6	7.2
	Difference	-0.5	0.1	0.4	-0.1
Glucose (mg %)	Pre	91.1	87.1	84.0	88.7
	Post	84.9	87.3	91.4	86.3
	Difference	-6.2	0.2	7.4	-2.4
Total Lipids (mg %)	Pre	369	564	493	498
	Post	401	632	463	486
	Difference	32	68	-30	-12
Cholesterol (mg %)	Pre	134	188	151	151
	Post	135	188	158	146
	Difference	1	0	7	-5
Triglycerides (mg %)	Pre	76	85	67	63
	Post	123	130	35	67
	Difference	47	45	-32	4
Phospholipids (mg %)	Pre	194	199	244	163
	Post	185	200	204	186
	Difference	-9	1	-40	23
Na^+ (meq/l)	Pre	145	148	147	143
	Post	148	149	148	144
	Difference	3	1	1	1
K^+ (meq/l)	Pre	5.3	5.2	5.5	4.9
	Post	5.5	5.4	5.4	4.8
	Difference	0.2	0.2	-0.1	-0.1

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Ca^{+2} (meq/l)	Pre	5.9	5.7	5.6	5.2
	Post	5.9	5.6	5.8	5.5
	Difference	-0.0	-0.1	0.2	0.3
BICYCLE TEST VARIABLES					
Time on Bike (min.)	Pre	25.2	25.4	24.2	22.0
	Post	20.8	24.2	21.2	21.2
	Difference	-4.4	-1.2	-3.0	-0.8
Systolic Blood Pressure at Rest (mm Hg)	Pre	126	126	126	121
	Post	123	128	138	113
	Difference	-3	2	12	-8
Systolic Blood Pressure at 25% Load (mm Hg)	Pre	144	142	147	141
	Post	146	148	157	132
	Difference	2	6	10	-9
Systolic Blood Pressure at 50% Load (mm Hg)	Pre	158	168	166	159
	Post	159	171	173	148
	Difference	1	3	7	-11
Systolic Blood Pressure at 75% Load (mm Hg)	Pre	175	181	184	177
	Post	182	187	196	176
	Difference	7	6	12	-1
Systolic Blood Pressure at 180 P.R. (mm Hg)	Pre	205	193	197	180
	Post	186	189	194	175
	Difference	-19	-4	-3	-5
Systolic Blood Pressure at Recovery (mm Hg)	Pre	140	150	150	138
	Post	140	146	148	129
	Difference	0	-4	-2	-9
Diastolic Blood Pressure at Rest (mm Hg)	Pre	78	74	74	76
	Post	73	79	77	75
	Difference	-5	5	3	-1
Diastolic Blood Pressure at 25% Load (mm Hg)	Pre	68	69	67	74
	Post	67	73	75	71
	Difference	-1	4	8	-3
Diastolic Blood Pressure at 50% Load (mm Hg)	Pre	64	68	64	73
	Post	65	66	69	70
	Difference	1	-2	5	-3
Diastolic Blood Pressure at 75% Load (mm Hg)	Pre	64	63	65	69
	Post	63	65	68	63
	Difference	-1	2	3	-6

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Diastolic Blood Pressure at 180 P.R. (mm Hg)	Pre	61	61	62	62
	Post	62	63	63	67
	Difference	1	2	1	5
Diastolic Blood Pressure at Recovery (mm Hg)	Pre	70	68	75	70
	Post	76	71	80	73
	Difference	6	3	5	3
Pulse Rate at Rest (beats/min.)	Pre	76.8	77.6	77.6	80.8
	Post	92.0	79.2	88.8	83.2
	Difference	15.2	1.6	11.2	2.4
Pulse Rate at 25% Load (beats/min.)	Pre	104.8	103.2	107.2	106.4
	Post	115.2	104.0	116.8	109.6
	Difference	10.4	0.8	9.6	3.2
Pulse Rate at 50% Load (beats/min.)	Pre	124.8	124.8	130.4	139.2
	Post	144.0	129.6	145.6	137.6
	Difference	19.2	4.8	15.2	-1.6
Pulse Rate at 75% Load (beats/min.)	Pre	145.0	152.0	159.2	168.0
	Post	169.0	160.0	172.0	172.8
	Difference	24.0	8.0	12.8	4.8
Pulse Rate at 180 (beats/min.)	Pre	180.0	180.0	178.4	179.2
	Post	180.0	180.8	180.0	178.4
	Difference	0.0	0.8	1.6	-0.8
Pulse Rate at Recovery (beats/min.)	Pre	107.0	116.0	109.6	104.8
	Post	117.0	105.6	115.2	112.8
	Difference	10.0	-10.4	5.6	8.0
$\dot{V}_E$ BTPS at Rest (l)	Pre	12.8	13.2	15.2	18.0
	Post	14.4	16.4	15.8	20.4
	Difference	1.6	3.2	0.6	2.4
$\dot{V}_E$ BTPS at 25% Load (l)	Pre	28.4	28.0	29.8	29.8
	Post	28.6	30.4	32.4	29.0
	Difference	0.2	2.4	2.6	-0.8
$\dot{V}_E$ BTPS at 50% Load (l)	Pre	44.4	40.8	43.4	41.2
	Post	45.6	43.8	46.4	42.8
	Difference	1.2	3.0	3.0	1.6
$\dot{V}_E$ BTPS at 75% Load (l)	Pre	63.0	60.0	62.2	61.6
	Post	67.0	70.4	64.6	61.4
	Difference	4.0	10.4	2.4	-0.2

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_E$ BTPS at 180 P.R. (1)	Pre	103.0	110.4	92.8	71.6
	Post	78.0	101.8	74.4	67.8
	Difference	-25.0	-8.6	-18.4	-3.8
$\dot{V}_E$ BTPS at Recovery (1)	Pre	20.7	26.0	24.0	19.2
	Post	18.2	24.6	19.2	19.0
	Difference	-2.5	-1.4	-4.8	-0.2
$\dot{V}_E$ STPD at Rest (1)	Pre	10.6	10.6	12.6	15.0
	Post	12.0	13.6	13.0	16.6
	Difference	1.4	3.0	0.4	1.6
$\dot{V}_E$ STPD at 25% Load (1)	Pre	23.8	23.4	25.0	24.8
	Post	24.2	25.2	26.8	24.0
	Difference	0.4	1.8	1.8	-0.8
$\dot{V}_E$ STPD at 50% Load (1)	Pre	37.0	34.0	36.2	34.2
	Post	38.4	36.2	38.8	35.4
	Difference	1.4	2.2	2.6	1.2
$\dot{V}_E$ STPD at 75% Load (1)	Pre	52.5	50.0	51.8	51.6
	Post	56.5	58.4	53.6	50.6
	Difference	4.0	8.4	1.8	-1.0
$\dot{V}_E$ STPD at 180 P.R. (1)	Pre	86.2	91.4	73.6	59.8
	Post	65.6	86.8	62.0	61.6
	Difference	-20.6	-4.6	-11.6	1.8
$\dot{V}_E$ STPD at Recovery (1)	Pre	17.7	21.8	20.2	16.2
	Post	15.5	20.0	15.8	16.0
	Difference	-2.2	-1.8	-4.4	-0.2
Respiratory Rate at Rest (breaths/min.)	Pre	16.0	12.0	13.2	11.2
	Post	16.8	13.0	15.6	16.8
	Difference	0.8	1.0	2.4	5.6
Respiratory Rate at 25% Load (breaths/min.)	Pre	21.6	19.2	23.0	18.0
	Post	21.2	18.2	25.0	23.0
	Difference	-0.4	-1.0	2.0	5.0
Respiratory Rate at 50% Load (breaths/min.)	Pre	23.6	21.6	24.0	20.2
	Post	25.2	23.2	26.6	22.4
	Difference	1.6	1.6	2.6	2.2

TABLE VI....MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Respiratory Rate at 75% Load (breaths/min.)	Pre	28.0	24.6	32.4	26.4
	Post	26.2	32.0	33.4	28.0
	Difference	-1.8	7.4	1.0	1.6
Respiratory Rate at 180 P.R. (breaths/min.)	Pre	37.4	39.4	41.6	33.4
	Post	29.2	41.6	40.4	32.4
	Difference	-8.2	2.2	-1.2	-1.0
Respiratory Rate at Recovery (breaths/min.)	Pre	18.5	20.0	17.4	16.2
	Post	17.7	20.4	17.0	18.2
	Difference	-0.8	0.4	-0.4	2.0
Tidal Volume at Rest (l)	Pre	0.78	1.12	1.12	1.76
	Post	0.82	1.24	1.04	1.42
	Difference	0.04	0.12	-0.08	-0.34
Tidal Volume at 25% Load (l)	Pre	1.34	1.48	1.36	1.90
	Post	1.38	1.86	1.28	1.54
	Difference	0.04	0.38	-0.08	-0.36
Tidal Volume at 50% Load (l)	Pre	1.90	1.94	1.82	2.48
	Post	1.82	1.90	1.78	2.24
	Difference	-0.08	-0.04	-0.04	-0.24
Tidal Volume at 75% Load (l)	Pre	2.25	2.44	1.98	2.62
	Post	2.55	2.24	1.98	2.42
	Difference	0.30	-0.20	0.00	-0.20
Tidal Volume at 180 P.R. (l)	Pre	2.80	2.68	2.14	2.32
	Post	2.62	2.50	1.86	2.30
	Difference	-0.18	-0.18	-0.28	-0.02
Tidal Volume at Recovery (l)	Pre	1.12	1.32	1.48	1.38
	Post	1.10	1.24	1.12	1.16
	Difference	-0.02	-0.08	-0.36	-0.22
$\dot{V}_{CO_2}$ at Rest (l)	Pre	0.299	0.304	0.371	0.452
	Post	0.354	0.346	0.380	0.442
	Difference	0.055	0.042	0.009	-0.010
$\dot{V}_{CO_2}$ at 25% Load (l)	Pre	0.831	0.847	0.909	0.903
	Post	0.902	0.904	0.882	0.814
	Difference	0.071	0.057	-0.027	-0.089
$\dot{V}_{CO_2}$ at 50% Load (l)	Pre	1.451	1.384	1.425	1.421
	Post	1.546	1.412	1.451	1.432
	Difference	0.095	0.028	0.026	0.011

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_{CO_2}$ at 75% Load (l)	Pre	2.075	2.073	2.045	2.084
	Post	2.278	2.209	2.035	1.994
	Difference	0.203	0.136	-0.010	-0.090
$\dot{V}_{CO_2}$ at 180 P.R. (l)	Pre	3.215	3.278	2.753	2.342
	Post	2.548	2.926	2.228	2.168
	Difference	-0.667	-0.352	-0.525	-0.174
$\dot{V}_{CO_2}$ at Recovery (l)	Pre	0.488	0.606	0.593	0.471
	Post	0.445	0.547	0.436	0.442
	Difference	-0.043	-0.059	-0.157	-0.028
$\dot{V}_{O_2}$ at Rest (l)	Pre	0.308	0.337	0.391	0.447
	Post	0.372	0.382	0.426	0.414
	Difference	0.064	0.045	0.035	-0.033
$\dot{V}_{O_2}$ at 25% Load (l)	Pre	0.958	0.983	1.096	0.992
	Post	1.012	1.054	1.064	0.942
	Difference	0.054	0.071	-0.032	-0.050
$\dot{V}_{O_2}$ at 50% Load (l)	Pre	1.586	1.543	1.608	1.507
	Post	1.645	1.569	1.633	1.521
	Difference	0.059	0.026	0.025	0.014
$\dot{V}_{O_2}$ at 75% Load (l)	Pre	2.181	2.189	2.247	2.113
	Post	2.317	2.366	2.227	2.177
	Difference	0.136	0.177	-0.020	0.064
$\dot{V}_{O_2}$ at 180 P.R. (l)	Pre	3.159	3.276	3.024	2.390
	Post	2.553	3.055	2.454	2.209
	Difference	-0.606	-0.221	-0.570	-0.181
$\dot{V}_{O_2}$ at Recovery (l)	Pre	0.495	0.634	0.595	0.487
	Post	0.479	0.591	0.487	0.482
	Difference	-0.016	-0.043	-0.108	-0.005
$\dot{V}_{O_2}$/pulse at Rest (ml)	Pre	4.08	4.60	5.32	5.44
	Post	4.10	4.80	5.14	4.94
	Difference	0.02	0.20	-0.18	-0.50
$\dot{V}_{O_2}$/pulse at 25% Load (ml)	Pre	9.22	9.64	10.38	9.42
	Post	9.00	10.22	9.28	8.68
	Difference	-0.22	0.58	-1.10	-0.74

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	GROUP B Quit Training	GROUP C Sleep Deprivation	GROUP D Control
$\dot{V}_{O_2}$/pulse at 50% Load (ml)	Pre	12.78	12.42	12.42	10.96
	Post	11.70	12.12	11.34	11.14
	Difference	-1.08	-0.30	-1.08	0.18
$\dot{V}_{O_2}$/pulse at 75% Load (ml)	Pre	15.05	14.44	14.14	12.66
	Post	13.77	14.74	13.02	12.56
	Difference	-1.27	0.30	-1.12	-0.10
$\dot{V}_{O_2}$/pulse at 180 P.R. (ml)	Pre	17.56	18.20	16.20	13.30
	Post	14.14	16.90	13.64	12.34
	Difference	-3.42	-1.30	-2.56	-0.96
$\dot{V}_{O_2}$/pulse at Recovery (ml)	Pre	4.62	5.52	5.52	4.74
	Post	4.10	5.70	4.22	4.34
	Difference	-0.52	0.18	-1.30	-0.40
$\dot{V}_{O_2}$/kgbw·min. at Rest (ml)	Pre	4.30	4.70	6.14	6.60
	Post	5.08	5.32	6.66	6.16
	Difference	0.78	0.62	0.52	-0.44
$\dot{V}_{O_2}$/kgbw·min. at 25% Load (ml)	Pre	13.24	13.72	17.04	14.88
	Post	13.88	14.78	16.70	14.36
	Difference	0.64	1.06	-0.34	-0.52
$\dot{V}_{O_2}$/kgbw·min. at 50% Load (ml)	Pre	21.90	21.58	25.02	22.56
	Post	22.50	21.96	25.66	23.16
	Difference	0.60	0.38	0.64	0.60
$\dot{V}_{O_2}$/kgbw·min. at 75% Load (ml)	Pre	29.67	30.58	34.98	31.78
	Post	31.25	33.14	34.94	32.82
	Difference	1.58	2.56	-0.04	1.04
$\dot{V}_{O_2}$/kgbw·min. at 180 P.R. (ml)	Pre	43.46	45.74	44.94	36.16
	Post	34.76	42.82	38.32	33.86
	Difference	-8.70	-2.92	-6.62	-2.30
$\dot{V}_{O_2}$/kgbw·min. at Recovery (ml)	Pre	7.05	8.86	9.28	7.36
	Post	6.72	8.28	7.64	7.34
	Difference	-0.33	-0.58	-1.64	-0.02
$\dot{V}_E/\dot{V}_{O_2}$ at Rest (l)	Pre	41.76	39.70	37.40	38.86
	Post	38.66	41.48	37.68	48.46
	Difference	-3.10	1.78	0.28	9.60

TABLE VI.... MEAN PRE- AND POST_STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... Continued

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
$\dot{V}_E/\dot{V}_{O_2}$ at 25% Load (1)	Pre	30.08	28.36	27.68	29.84
	Post	28.28	28.64	30.18	30.84
	Difference	-1.80	0.28	2.50	1.00
$\dot{V}_E/\dot{V}_{O_2}$ at 50% Load (1)	Pre	28.22	26.32	27.42	27.14
	Post	27.76	27.88	28.58	28.20
	Difference	-0.46	1.56	1.16	1.06
$\dot{V}_E/\dot{V}_{O_2}$ at 75% Load (1)	Pre	29.05	27.26	28.04	29.12
	Post	29.02	29.46	29.06	28.18
	Difference	-0.03	2.20	1.02	-0.94
$\dot{V}_E/\dot{V}_{O_2}$ at 180 P.R. (1)	Pre	32.60	33.48	30.58	30.76
	Post	29.96	33.26	29.96	31.28
	Difference	-2.64	-0.22	-0.62	0.52
$\dot{V}_E/\dot{V}_{O_2}$ at Recovery (1)	Pre	42.65	41.06	41.24	39.40
	Post	38.42	41.70	39.44	39.84
	Difference	-4.23	0.64	-1.80	0.44
Cardiac Output at Rest (l/min)	Pre	4.32	3.50	6.02	5.32
	Post	5.16	3.18	4.86	5.44
	Difference	0.84	-0.32	-1.16	0.12
Cardiac Output at 25% Load (l/min)	Pre	8.32	8.84	10.06	8.80
	Post	9.36	8.62	9.32	8.32
	Difference	1.04	-0.22	-0.74	-0.48
Cardiac Output at 50% Load (l/min)	Pre	11.12	12.16	12.86	11.00
	Post	11.26	12.70	12.50	11.14
	Difference	0.14	0.54	-0.36	0.14
Cardiac Output at 75% Load (l/min)	Pre	13.40	14.52	13.80	13.88
	Post	13.65	13.50	14.72	13.50
	Difference	0.25	-1.02	0.92	-0.38
Cardiac Output at Recovery (l/min)	Pre	8.32	8.24	8.28	8.40
	Post	8.90	7.80	7.82	7.34
	Difference	0.58	-0.44	-0.46	-1.06
Respiratory Exchange Ratio at Rest	Pre	0.958	0.898	0.916	0.982
	Post	0.942	0.886	0.886	1.066
	Difference	-0.016	-0.012	-0.030	0.084

TABLE VI.... MEAN PRE- AND POST-STRESS VALUES OF THE MEASURED VARIABLES BY GROUPS.... *Continued*

VARIABLE		GROUP A Bed Rest	B Quit Training	C Sleep Deprivation	D Control
Respiratory Exchange Ratio at 25% Load	Pre	0.866	0.856	0.828	0.902
	Post	0.890	0.854	0.822	0.866
	Difference	0.024	-0.002	-0.006	-0.036
Respiratory Exchange Ratio at 50% Load	Pre	0.916	0.898	0.888	0.942
	Post	0.940	0.900	0.894	0.942
	Difference	0.024	0.002	0.006	0.000
Respiratory Exchange Ratio at 75% Load	Pre	0.957	0.948	0.912	0.982
	Post	0.987	0.938	0.916	0.924
	Difference	0.030	-0.010	0.004	-0.058
Respiratory Exchange Ratio at 180 P.R.	Pre	1.016	1.000	0.952	0.982
	Post	0.992	0.958	0.900	0.980
	Difference	-0.024	-0.042	-0.052	-0.002
Respiratory Exchange Ratio at Recovery	Pre	0.985	0.954	0.994	0.966
	Post	0.935	0.928	0.900	0.918
	Difference	-0.050	-0.026	-0.094	-0.048

References

1. Consolazio, C. F.; R. E. Johnson; and L. J. Pecora, Physiological Measurements of Metabolic Functions in Man, McGraw-Hill Book Company: New York, 1963, p. 221.
2. Clarke, H. H., Application of Measurement to Health and Physical Education, Prentice-Hall, Inc.: Englewood Cliffs, New Jersey, 1959, pp. 183-209.
3. Clarke, H. H. and R. A. Munroe, Test Manual. Oregon Cable-Tension Strength Test Batteries for Boys and Girls from Fourth Grade Through College, University of Oregon: Eugene, Oregon, 1970, pp. 13-30, 55-61.
4. Sunderman, F. W., Lipids and Steroid Hormones in Clinical Medicine, J. B. Lippincott: Philadelphia, 1960, pp. 28-31.
5. Kim, T. S.; H. Rahn; and L. E. Farhi, "Estimation of True Venous and Arterial P_{CO_2} by Gas Analysis of a Single Breath," Journal of Applied Physiology 21:1338-44, 1966.
6. Buderer, Melvin C.; John A. Rummel; Charles F. Sawin; and Donald G. Mauldin, "Use of the Single-Breath Method of Estimating Cardiac Output During Exercise Stress Testing," Unpublished Manuscript.